

Chapter 1. Introduction

Welcome to the Llama book, our affectionate name for our book covering Perl 5.

This is the eighth edition of a book that millions of readers have enjoyed since we released the first one in 1993. We hope they've enjoyed it. It's a sure thing that we enjoyed writing it. At least, that's how we remember it after we've turned in the book and waited the months it took to see it show up on shelves. And by "shelves," we mean online.

This is the second edition of our popular Perl 5 book after the release of Perl 6, a language that started its life as something based on Perl but has now taken on a life of its own with the new name "Raku." Unfortunately, that bit of history means both languages have "Perl" in the name even though they are only lightly related. It's likely that you want Perl 5 and this book unless you know that you don't. And from this point, "Perl" means Perl 5, the same Perl that's been getting work done for a couple of decades.

Questions and Answers

You probably have some questions about Perl, and maybe even some about this book, especially if you've already flipped through it to see what's coming. So, we'll use this chapter to answer them, including how to find answers that we *don't* provide.

Is This the Right Book for You?

This is not a reference book. It's a tutorial on the very basics of Perl, which is just enough for you to create simple programs mostly for your own use. We don't cover every detail of every topic, and we spread out some of the topics over several chapters so that you pick up concepts as you need them.

Our intended readers are people who know at least a little bit about programming and just need to learn Perl. We assume you have at least some background in using a terminal, editing files, and running programs—just not Perl programs. You already know about variables and subroutines and the like, but you just need to see how Perl does it.

This doesn't mean that the absolute beginner, having never touched a terminal program or written a single line of code, will be completely lost. You might not catch everything we say the first time you go through the book, but many beginners have used the book with only minor frustrations. The trick is to not worry about everything you might be missing and to focus on just the core concepts we present. You might take a little longer than an experienced programmer, but you have to start somewhere.

We're assuming you know a little about Unicode, so we don't bog down in the details, but we've explained a bit more in [Appendix C](#). You can peruse it before you start the book and refer to it as needed.

We've included an appendix on experimental features ([Appendix D](#)). Some exciting new things await you, but we're not going to force you to use them. Whenever possible, we'll try to show you how to do the same amazing thing the old boring way.

And this shouldn't be the only Perl book you ever read. It's just a tutorial. It's not comprehensive. We get you started in the right direction so you can go on to our other books, *Intermediate Perl* and *Mastering Perl*, when you are ready. The definitive reference for Perl is *Programming Perl*, also known as the “Camel book.”

We should also note that even though this book covers up to Perl 5.34, it's still useful even if you have an earlier version. You might miss out on some

of the cool new features, but you'll still learn how to use basic Perl. The least recent version that we'll think about, however, is Perl 5.8, even though that was released almost 20 years ago.

What About the Exercises and Their Answers?

We've included exercises at the end of each chapter because, between the three of us, we've presented this same course material to several thousand students. We know that making mistakes by working through the exercises is the best way to learn. We have carefully crafted these exercises to give you the chance to make mistakes as well.

It's not that we *want* you to make mistakes, but you need to have the *chance*. You're going to make most of these mistakes during your Perl programming career, and it may as well be now. Any mistake that you make while reading this book you won't make again when you're writing a program on a deadline. And we're always here to help you out if something goes wrong, in the form of **Appendix A**, which has our answers for each exercise and a little text to go with it. Check out the answers when you're done with the exercises.

Try not to peek at the answer until you've given the problem a good try, though. You'll learn better if you figure it out rather than read about it. Don't knock your head repeatedly against the wall if you don't figure out a solution: move on to the next chapter and don't worry too much about it.

Even if you never make any mistakes, you should look at the answers when you're done; the accompanying text will point out some details of the program that might not be obvious at first.

When you look at our answer, keep in mind that you could have done it in a different manner and still be right. You don't have to do the same thing we did. In some cases, we'll have multiple solutions. Not only that, but after you make it through this book, you'll probably do the same task differently since we've limited our answers to only the concepts we've shown so far. Other features you encounter later might make short work of the problem.

Each exercise has a number in square brackets in front of the exercise text, looking something like this:

1. [37] What does the number 37 inside square brackets mean, when it appears at the start of an exercise’s text?

That number is our (very rough) estimate of how many minutes you can expect to spend on that particular exercise. It’s rough, so don’t be too surprised if you’re all done (with writing, testing, and debugging) in half that time, or not done in twice that long. On the other hand, if you’re really stuck, we won’t tell anyone that you peeked at [Appendix A](#) to see our answer.

If you want additional exercises, check out the *Learning Perl Exercises*, which adds several exercises for each chapter.

What If I’m a Perl Course Instructor?

If you’re a Perl instructor who has decided to use this as your textbook (as many have over the years), you should know that we’ve tried to make each set of exercises short enough that most students could do the whole set in 45 minutes to an hour, with a little time left over for a break. Some chapters’ exercises should be quicker, and some may take longer. That’s because, once we had written all of those little numbers in square brackets, we discovered we don’t know how to add (luckily we know how to make computers do it for us).

We also have a companion book, the *Learning Perl Exercises*, which has additional exercises for each chapter. If you get the version of the workbook for previous editions, you might have to adjust the chapter order.

What Does “Perl” Stand For?

Perl is sometimes called the “Practical Extraction and Report Language,” although it has also been called a “Pathologically Eclectic Rubbish Lister,” among other expansions. It’s actually a backronym, not an acronym—Larry

Wall, Perl's creator, came up with the name first and the expansion later. That's why "Perl" isn't in all caps. There's no point in arguing which expansion is correct: Larry endorses both.

You may also see "perl" with a lowercase *p* in some writing. In general, "Perl" with a capital *P* refers to the language and "perl" with a lowercase *p* refers to the actual interpreter that compiles and runs your programs.

Why Did Larry Create Perl?

Larry created Perl in the mid-1980s when he was trying to produce some reports from a Usenet-news-like hierarchy of files for a bug-reporting system, and *awk* ran out of steam. Larry, being the lazy programmer that he is, decided to overkill the problem with a general-purpose tool that he could use in at least one other place. The result was Perl version zero.

We're not insulting Larry by saying he's lazy; Laziness is a virtue. So are Impatience and Hubris, as Larry wrote in the first edition of *Programming perl*. The wheelbarrow was invented by someone who was too lazy to carry things; writing was invented by someone who was too lazy to memorize; Perl was invented by someone who was too lazy to get the job done without inventing a whole new computer language.

Why Didn't Larry Just Use Some Other Language?

There's no shortage of computer languages, is there? But at the time, Larry didn't see anything that really met his needs. If one of the other languages of today had been available back then, perhaps Larry would have used one of those. He needed something with the quickness of coding available in shell or *awk* programming, and with some of the power of more advanced tools like *grep*, *cut*, *sort*, and *sed*, without having to resort to a language like C.

Perl tries to fill the gap between low-level programming (such as in C or C++ or assembly) and high-level programming (such as shell programming). Low-level programming is usually hard to write and ugly, but fast and unlimited; it's hard to beat the speed of a well-written low-level

program on a given machine. And there's not much you can't do there. High-level programming, at the other extreme, tends to be slow, hard, ugly, and limited; there are many things you can't do at all with the shell or batch programming if there's no command on your system that provides the needed functionality. Perl is easy, nearly unlimited, mostly fast, and kind of ugly.

Let's take another look at those four claims we just made about Perl.

First, *Perl is easy*. As you'll see, though, this means it's easy to *use*. It's not especially easy to *learn*. If you drive a car, you spent many weeks or months learning how, and now it's easy to drive. When you've been programming Perl for about as many hours as it took you to learn to drive, Perl will be easy for you.

Perl is nearly unlimited. There are very few things you can't do with Perl. You wouldn't want to write an interrupt-microkernel-level device driver in Perl (even though that's been done), but most things that ordinary folks need most of the time are good tasks for Perl, from quick little one-off programs to major industrial-strength applications.

Perl is mostly fast. That's because nobody is developing Perl who doesn't also use it—so we all want it to be fast. If someone wants to add a feature that would be really cool but would slow down other programs, the Perl developers are almost certain to refuse the new feature until we find a way to make it quick enough.

Perl is kind of ugly. This is true. The symbol of Perl has become the camel, from the cover of the venerable Camel book (also known as *Programming Perl*), a cousin of this book's Llama (and her sister, the Alpaca). Camels are kind of ugly, too. But they work hard, even in tough conditions. Camels are there to get the job done despite all difficulties, even when they look bad and smell worse and sometimes spit at you. Perl is a little like that.

Is Perl Easy or Hard?

Perl is easy to use, but sometimes hard to learn. This is a generalization, of course. In designing Perl, Larry made many trade-offs. When he's had the chance to make something easier for the programmer at the expense of being more difficult for the student, he's decided in the programmer's favor nearly every time. That's because you'll learn Perl only once, but you'll use it again and again.

If you're going to use a programming language for only a few minutes each week or month, you'd prefer one that is easier to learn since you'll have forgotten nearly all of it from one use to the next. Perl is for people who are programmers for at least 20 minutes per day, and probably most of that in Perl.

Perl has any number of conveniences that let the programmer save time. For example, most functions will have a default; frequently, the default is the way that you'll want to use the function. So you'll see lines of Perl code like these:

```
while (<>) {  
    chomp;  
    print join("\t", (split /:/)[0, 2, 1, 5] ), "\n";  
}
```

Don't worry that you don't know what any of that means yet. Written out in full, without using Perl's defaults and shortcuts, that snippet would be roughly 10 or 12 times longer, so it would take much longer to read and write. It would be harder to maintain and debug, too, with more variables. If you already know some Perl and you don't see the variables in that code, that's part of the point. They're all being used by default. But to have this ease at the programmer's tasks means paying the price when you're learning; you have to learn those defaults and shortcuts.

A good analogy is the proper and frequent use of contractions in English. Sure, "will not" means the same as "won't." But most people say "won't" rather than "will not" because it saves time, and because everybody knows it and it makes sense. Similarly, Perl's "contractions" abbreviate common

“phrases” so that they can be “spoken” quicker and understood by the maintainer as a single idiom rather than a series of unrelated steps.

Once you become familiar with Perl, you may find yourself spending less time trying to get shell quoting (or C declarations) right, and more time surfing the web because Perl is a great tool for leverage. Perl’s concise constructs allow you to create (with minimal fuss) some very cool one-up solutions or general tools. Also, you can drag those tools along to your next job because Perl is highly portable and readily available, so you’ll have even more time to surf.

Perl is a very high-level language. That means the code is quite dense; a Perl program may be around a quarter to three-quarters as long as the corresponding program in C. This makes Perl faster to write, faster to read, faster to debug, and faster to maintain. It doesn’t take much programming before you realize that, when the entire subroutine is small enough to fit onscreen all at once, you don’t have to keep scrolling back and forth to see what’s going on. Also, since the number of bugs in a program is roughly proportional to the length of the source code (rather than being proportional to the program’s functionality), the shorter source in Perl will mean fewer bugs on average.

Like any language, Perl can be “write-only”—it’s possible to write programs that are impossible to read. But with proper care, you can avoid this common accusation. Yes, sometimes Perl looks like line noise to the uninitiated, but to the seasoned Perl programmer, it looks like the notes of a grand symphony. If you follow the guidelines of this book, your programs should be easy to read and easy to maintain, and they probably won’t win an Obfuscated Perl Contest.

How Did Perl Get to Be So Popular?

After playing with Perl a bit, adding stuff here and there, Larry released it to the community of Usenet readers, commonly known as “the Net.” The users on this ragtag fugitive fleet of systems around the world (tens of thousands

of them) gave him feedback, asking for ways to do this, that, or the other thing, many of which Larry had never envisioned his little Perl handling.

But as a result, Perl grew, and grew, and grew. It grew in features. It grew in portability. What was once a little language available on only a couple of Unix systems now has thousands of pages of free online documentation, dozens of books, several mainstream Usenet newsgroups (and a dozen newsgroups and mailing lists outside the mainstream) with an uncountable number of readers, and implementations on nearly every system in use today—and don’t forget this Llama book as well.

What’s Happening with Perl Now?

Perl 5 development underwent an amazing revitalization while most people were waiting for its successor, Perl 6. Those are actually different languages now, but Perl 5, which is still doing a lot of good work in the world, keeps chugging along. They shared a name for awhile, but Perl 6 is now on its own as “Raku” (although brian’s book on that language is still titled *Learning Perl 6*).

Starting with v5.10, Perl developed a way to include new features in the language without disturbing old programs. We’ll show you how to get those new features when you want them, as well as how to enable experimental features that you might want to play with. You can peek at [Appendix D](#) for more details.

The Perl 5 Porters also adopted an official support policy. After 20 years of playing it fast and loose, they decided they would support the last two stable releases. By the time we’re finished with this book, we expect those to be v5.32 and v5.34. The odd numbers after the dot are reserved for development releases.

In 2019, Perl development moved to GitHub. That means you can now easily file issues, send pull requests, and check out the “bleeding” edge sources. This frees up a lot of the effort that formerly went into maintaining the aging infrastructure.

There's also talk of a new major version of Perl, Perl 7, which will be mostly v5.34 with different defaults. Learning the current version of Perl means you should be ready for Perl 7. brian covers some things to expect in *Preparing for Perl 7*, and we'll add notes in this book when we can.

What's Perl Really Good For?

Perl is good for quick-and-dirty programs that you whip up in three minutes. Perl is also good for long and extensive programs that will take a dozen programmers three years to finish. Of course, you'll probably find yourself writing many programs that take you less than an hour to complete, from the initial plan to the fully tested code.

Perl is optimized for problems that are about 90% working with text and about 10% everything else. That description seems to fit most programming tasks that pop up these days. In a perfect world, every programmer would know every language; you'd always be able to choose the best language for each project. Most of the time, we hope you'd choose Perl.

What Is Perl Not Good For?

So, if it's good for so many things, what is Perl *not* good for? Well, you shouldn't choose Perl if you're trying to make an *opaque binary*. That's a program that you could give away or sell to someone who then can't see your secret algorithms in the source, and thus can't help you maintain or debug your code either. When you give someone your Perl program, you'll normally be giving them the source, not an opaque binary.

If you're wishing for an opaque binary, though, we have to tell you that they don't exist. If someone can install and run your program, they can turn it back into source code. Granted, this won't necessarily be the same source you started with, but it will be some kind of source code. The real way to keep your secret algorithm a secret is, alas, to apply the proper number of attorneys; they can write a license that says, "You can do *this* with the code, but you can't do *that*. And if you break our rules, we've got the proper number of attorneys to ensure that you'll regret it."

How Can I Get Perl?

You probably already have it. At least, we find Perl wherever *we* go. It ships with many systems, and system administrators often install it on every machine at their site. But if you can't find it already on your system, you can still get it for free. It comes pre-installed with most Linux or *BSD systems, macOS, and some others. Companies such as [ActiveState](#) provide pre-built and enhanced distributions for several platforms, including Windows. You can also get [Strawberry Perl for Windows](#), which comes with all the same stuff as regular Perl plus extra tools to compile and install third-party modules.

Perl is distributed under two different licenses. For most people, since you'll merely be *using* it, either license is as good as the other. If you'll be modifying Perl, however, you'll want to read the licenses more closely, because they put some small restrictions on distributing the modified code. For people who won't modify Perl, the licenses essentially say, "It's free—have fun with it."

In fact, it's not only free, but it runs rather nicely on nearly everything that calls itself Unix and has a C compiler. You download it, type a command or two, and it starts configuring and building itself. Or, better yet, you get your package manager to do it for you. Besides Unix and Unix-like systems, people addicted to Perl have ported it to other systems, such as VMS, OS/2, even MS-DOS, and every modern species of Windows—and probably even more by the time you read this. Many of these ports of Perl come with an installation program that's even easier to use than the process for installing Perl in Unix. Check for links in the "ports" section on CPAN.

It's nearly always better to compile Perl from the source in Unix systems. Other systems may not have a C compiler and other tools needed for compilation, so CPAN has binaries for these. When you use your local package manager, you're changing the *perl* that your system may use to do its own tasks. You might make a big mess. We suggest you install a *perl* just for your use, but that's not necessary for this book.

What Is CPAN?

CPAN is the Comprehensive Perl Archive Network, your one-stop shop for Perl. It has the source code for Perl itself, ready-to-install ports of Perl to all sorts of non-Unix systems, examples, documentation, extensions to Perl, and archives of messages about Perl. In short, CPAN is comprehensive.

CPAN is replicated on hundreds of mirror machines around the world; start at [metacpan](#) to browse or search the archive.

Is There Any Kind of Support?

Sure. One of our favorites is the [Perl Mongers](#). This is a worldwide association of Perl users groups. There's probably a group near you with an expert or someone who knows an expert. If there's no group, you can easily start one.

Of course, for the first line of support, you shouldn't neglect the documentation. Besides the included documentation, you can also read the documentation on CPAN, [MetaCPAN](#), as well as other sites that have the [Perl documentation](#), and check out the latest version of the [perlfaq](#).

Another authoritative source is the book *Programming Perl*, commonly called “the Camel book” because of its cover animal (just as this book is known as “the Llama book”). The Camel book contains the complete reference information, some tutorial stuff, and a bunch of miscellaneous information about Perl. There's also a separate pocket-sized *Perl 5 Pocket Reference* by Johan Vromans (O'Reilly) that's handy to keep at hand (or in your pocket).

If you need to ask a question, there are any number of mailing lists—many listed at <http://lists.perl.org>. There's also [The Perl Monastery](#) and [Stack Overflow](#). At any hour of the day or night, there's a Perl expert awake in some time zone answering questions somewhere—the sun never sets on the Perl empire. This means that if you ask a question, you'll often get an answer within minutes. And if you didn't check the documentation and FAQ first, you'll get flamed within minutes.

You can also check out <http://learn.perl.org> and its associated mailing list, beginners@perl.org. Many well-known Perl programmers also have blogs that regularly feature Perl-related posts, most of which you can read through [/r/perl on Reddit](#).

If you find yourself needing a support contract for Perl, there are a number of firms that are willing to charge as much as you'd like. In most cases, these other support avenues will take care of you for free.

What If I Find a Bug in Perl?

As a new Perl programmer, you're likely to create a situation where you think something is wrong with Perl. You're using a big language that you don't know yet, so you don't know who to blame for the unexpected behavior. It happens.

The first thing to do when you find a bug is to check the documentation again. Maybe even two or three times. Many times, we've gone into the documentation looking to explain a particular unexpected behavior and found some new little nuance that ends up on a slide or in a magazine article. Perl has so many special features and exceptions to rules that you may have discovered a feature, not a bug. Also, check that you don't have an older version of Perl; maybe you found something that's been fixed in a more recent version.

Once you're 99% certain that you've found a real bug, ask around. Ask someone at work, at your local Perl Mongers meeting, or at a Perl conference. Chances are, it's *still* a feature, not a bug.

When you're 100% certain that you've found a real bug, cook up a test case. (What, you haven't done so already?) The ideal test case is a tiny self-contained program that any Perl user could run to see the same (mis-)behavior as you've found. Once you've got a test case that clearly shows the bug, create an issue on GitHub at <https://github.com/Perl/perl5/issues>.

Once you've sent off your bug report, if you've done everything right, it's not unusual to get a response within minutes. Typically, you can apply a simple patch and get right back to work. Of course, you may (at worst) get no response at all; the Perl developers are under no obligation to read your bug reports. But all of us love Perl, so nobody likes to let a bug escape our notice.

How Do I Make a Perl Program?

It's about time you asked (even if you didn't). Perl programs are text files; you can create and edit them with your favorite text editor. You don't need any special development environment, although there are some commercial ones available from various vendors. We've never used any of these enough to recommend them (but long enough to stop using them). Besides, your environment is a personal choice. Ask three programmers what you should use and you'll get eight answers.

You should generally use a programmer's text editor rather than an ordinary editor. What's the difference? Well, a programmer's text editor will let you do things that programmers need, like indenting or un-indenting a block of code, or finding the matching closing curly brace for a given opening curly brace.

On Unix systems, the two most popular programmer editors are *emacs* and *vi* (and their variants and clones). BBEdit, TextMate, and Sublime Text are good editors for macOS, and a lot of people have said nice things about UltraEdit, SciTE, Komodo Edit, and PFE (Programmer's File Editor) in Windows. The [perlfaq3 documentation](#) lists several other editors too. Ask your local expert about text editors on your system.

For the simple programs you'll write for the exercises in this book, none of which should be more than about 20 or 30 lines of code, any text editor will be fine.

Some beginners try to use a word processor instead of a text editor. We recommend against this—it's inconvenient at best and impossible at worst.

But we won't try to stop you. Be sure to tell the word processor to save your file as "text only"; the word processor's own format will almost certainly be unusable. Most word processors will probably also tell you that your Perl program is spelled incorrectly and you should use fewer semicolons.

In some cases, you may need to compose the program on one machine, then transfer it to another to run it. If you do this, be sure that the transfer uses "text" or "ASCII" mode, and not "binary" mode. This step is needed because of the different text formats on different machines. Without it, you may get inconsistent results—some versions of Perl actually abort when they detect a mismatch in the line endings.

A Simple Program

According to the oldest rule in the book, any book about a computer language that has Unix-like roots has to start with showing the "Hello, world" program. So, here it is in Perl:

```
#!/usr/bin/perl
print "Hello, world!\n";
```

Let's imagine that you've typed that into your text editor. (Don't worry yet about what the parts mean and how they work. You'll see about those in a moment.) You can generally save that program under any name you wish. Perl doesn't require any special kind of filename or extension, and it's better not to use an extension at all. But some systems may require an extension like *.plx* (meaning PerL eXecutable).

You may also need to do something so that your system knows it's an executable program (that is, a command). What you'll do depends on your system; maybe you won't have to do anything more than save the program in a certain place. (Your current directory will generally be fine.) On Unix systems, you mark a program as being executable using the *chmod* command:

```
$ chmod a+x my_program
```

The dollar sign (and space) at the start of the line represents the shell prompt, which will probably look different on your system. If you're used to using *chmod* with a number like 755 instead of a symbolic parameter like *a+x*, that's fine too, of course. Either way, it tells the system that this file is now a program.

Now you're ready to run it:

```
$ ./my_program
```

The dot and slash at the start of this command mean to find the program in the current working directory instead of looking through *PATH* to find a program. That's not needed in all cases, but you should use it at the start of each command invocation until you fully understand what it's doing.

You can also run this by explicitly stating *perl*. If you're in Windows, you must specify *perl* on the command line because Windows won't guess the program you want to run:

```
C:\> perl my_program
```

If everything worked, it's a miracle. More often, you'll find that your program has a bug. Edit and try again—but you don't need to use *chmod* each time, as that should “stick” to the file. (Of course, if the bug is that you didn't use *chmod* correctly, you'll probably get a “permission denied” message from your shell.)

There's another way to write this simple program in v5.10 or later, and we might as well get that out of the way right now. Instead of *print*, we use *say*, which does almost the same thing but with less typing. It adds the newline for us, meaning that we can save some time forgetting to add it ourselves. Since it's a new feature and you might not be using Perl 5.10 yet, we include a *use v5.10* statement that tells Perl we used new features:


```
#!/usr/bin/perl
use v5.10;

say "Hello World!";
```

This program only runs under v5.10 or later. When we introduce features from v5.10 or later in this book, we'll explicitly say they are new features in the text and include that `use v5.10` statement to remind you.

Typically, we only require the earliest version of Perl for the features that we need. This book covers up to v5.34, and in many of the new features we preface the examples to remind you the minimum version of Perl that you need for a feature:

```
use v5.34;
```

We could also write this version requirement without the `v`, but we have to remember that the minor number is actually three digits:

```
use 5.034;
```

Instead of that, we'll use the `v` form throughout this book.

What's Inside That Program?

Like other “free-form” languages, Perl generally lets you use insignificant whitespace (like spaces, tabs, and newlines) at will to make your program easier to read. Most Perl programs use a fairly standard format, though, much like most of what we show here. There is some general advice (not rules!) in the [perlstyle documentation](#). We strongly encourage you to properly indent your programs, as that makes your programs easier to read; a good text editor will do most of the work for you. Good comments also make a program easier to read. In Perl, comments run from a pound sign (`#`) to the end of the line.

NOTE

There are no “block comments” in Perl, but there are a number of ways to fake them. See the [perlfaq portions of the documentation](#).

We don’t use many comments in the programs in this book because the surrounding text explains their workings, but you should use comments as needed in your own programs.

So, another way (a very strange way, it must be said) to write that same “Hello, world” program might be like this:

```
#!/usr/bin/perl
    print    # This is a comment
    "Hello, world!\n"
;    # Don't write your Perl code like this!
```

That first line is actually a very special comment. On Unix systems, if the very first two characters on the first line of a text file are `#!` (pronounced “sh-bang,” or SHə'baNG for you dictionary nerds), then what follows is the name of the program that actually executes the rest of the file. In this case, the program is stored in the file `/usr/bin/perl`.

This `#!` line is actually the least portable part of a Perl program because you’ll need to find out what goes there for each machine. Fortunately, it’s almost always either `/usr/bin/perl` or `/usr/local/bin/perl`. If that’s not it, you’ll have to find where your system is hiding *perl*, then use that path. On some Unix systems, you might use a shebang line that finds *perl* for you:

```
#!/usr/bin/env perl
```

Beware though, that finds the first *perl*, which might not be the one that you wanted. If *perl* is not in any of the directories in your search path, you might have to ask your local system administrator or somebody using the same system as you.

On non-Unix systems, it's traditional (and even useful) to make the first line say `#!perl`. If nothing else, it tells your maintenance programmer as soon as they get ready to fix it that it's a Perl program.

If that `#!` line is wrong, you'll generally get an error from your shell. This may be something unexpected, like "file not found" or "bad interpreter." It's not your program that's not found, though; it's that `/usr/bin/perl` wasn't where it should have been. We'd make the message clearer if we could, but it's not coming from Perl; it's the shell that's complaining.

Another problem you could have is that your system doesn't support the `#!` line at all. In that case, your shell (or whatever your system uses) will probably try to run your program all by itself, with results that may disappoint or astonish you. If you can't figure out what some strange error message is telling you, search for it in the [perldiag documentation](#).

The "main" program consists of all the ordinary Perl statements (not including anything in subroutines, which you'll see later). There's no "main" routine, as there is in languages like C or Java. In fact, many programs don't even have routines (in the form of subroutines).

There's also no required variable declaration section, as there is in some other languages. If you've always had to declare your variables, you may be startled or unsettled by this at first. But it allows us to write quick-and-dirty Perl programs. If your program is only two lines long, you don't want to have to use one of those lines just to declare your variables. If you really want to declare your variables, that's a good thing; you'll see how to do that in [Chapter 4](#).

Most statements are an expression followed by a semicolon. Here's the one you've seen a few times so far:

```
print "Hello, world!\n";
```

You really only need semicolons to separate statements, not terminate them. You could leave the semicolon off if there's no statement following it (or it's the last statement in a scope):

```
print "Hello, world!\n"
```

As you may have guessed by now, this line prints the message `Hello, world!`. At the end of that message is the shortcut `\n`, which is probably familiar to you if you've used another language like C, C++, or Java; it means a newline character. When that's printed after the message, the print position drops down to the start of the next line, allowing the following shell prompt to appear on a line of its own, rather than being attached to the message. Every line of output should end with a newline character. We'll see more about the newline shortcut and other so-called backslash escapes in the next chapter.

How Do I Compile My Perl Program?

Just run your Perl program. The *perl* interpreter compiles and runs your program in one user step:

```
$ perl my_program
```

When you run your program, Perl's internal compiler first runs through your entire source, turning it into internal *bytecodes*, which is an internal data structure representing the program. Perl's bytecode engine takes over and actually runs the bytecode. If there's a syntax error on line 200, you'll get that error message before you start running line 2. If you have a loop that runs 5,000 times, it's compiled just once; the actual loop can then run at top speed. And there's no runtime penalty for using as many comments and as much whitespace as you need to make your program easy to understand. You can even use calculations involving only constants, and the result is a constant computed once as the program is beginning—not each time through a loop.

To be sure, this compilation does take time—it's inefficient to have a voluminous Perl program that does one small quick task (out of many potential tasks, say) and then exits because the runtime for the program will

be dwarfed by the compile time. But the compiler is very fast; normally the compilation will be a tiny percentage of the runtime.

What if you could save the compiled bytecodes to avoid the overhead of compilation? Or, even better, what if you could turn the bytecodes into another language, like C, and then compile that? Well, both of these things are possible in some cases, but they probably won't make most programs any easier to use, maintain, debug, or install, and they may even make your program slower.

A Whirlwind Tour of Perl

So, you want to see a real Perl program with some meat? (If you don't, just play along for now.) Here you are:

```
#!/usr/bin/perl
@lines = `perldoc -u -f atan2`;
foreach (@lines) {
    s/\w<(.+?)>/\U$1/g;
    print;
}
```

NOTE

If *perldoc* is not available, that probably means your system doesn't have a command-line interface or your particular system includes it in a different package.

Now, the first time you see Perl code like this, it can seem pretty strange. (In fact, every time you see Perl code like this, it can seem pretty strange.) But let's take it line by line and see what this example does. These explanations are very brief; this is a whirlwind tour, after all. We'll see all of this program's features in more detail in upcoming chapters. You're not really supposed to understand the whole thing until later.

The first line is the `#!` line, as you saw before. You might need to change that line for your system, as we showed you earlier.

The second line runs an external command, named within backquotes (``` ```). (The backquote key is often found next to the number 1 on full-size American keyboards. Be sure not to confuse the backquote with the single quote, `'`.) The command we used is `perldoc -u -f atan2`; try typing that in your command line to see what its output looks like. The `perldoc` command is used on most systems to read and display the documentation for Perl and its associated extensions and utilities, so it should normally be available. This command tells you something about the trigonometric function `atan2`; we're using it here just as an example of an external command whose output we wish to process.

The output of that command in the backquotes is saved in an array variable called `@lines`. The next line of code starts a loop that will process each one of those lines. Inside the loop, the statements are indented. Although Perl doesn't require this, good programmers do.

The first line inside the loop body is the scariest one; it says `s/\w<(.+?)>/\U$1/g;`. Without going into too much detail, we'll just say that this can change any line that has a special marker made with angle brackets (`<` `>`), and there should be at least one of those in the output of the `perldoc` command.

The next line, in a surprise move, prints out each (possibly modified) line. The resulting output should be similar to what `perldoc -u -f atan2` would do on its own, but there will be a change where any of those markers appear.

Thus, in the span of a few lines, you've run another program, saved its output in memory, updated the memory items, and printed them out. This kind of program is a fairly common use of Perl, where one type of data is converted to another.

Exercises

Normally, each chapter will end with some exercises, with the answers in [Appendix A](#). But you don't need to write the programs needed to complete this section—those are supplied within the chapter text.

If you can't get these exercises to work on your machine, double-check your work and then consult your local expert. Remember that you may need to tweak each program a little, as described in the text:

1. [7] Type in the “Hello, world” program and get it to work! You may name it anything you wish, but a good name might be *ex1-1*, for simplicity, as it's Exercise 1 in **Chapter 1**. This is a program that even an experienced programmer would write, mostly to test the setup of a system. If you can run this program, your *perl* is working.
2. [5] Type the command *perldoc -u -f atan2* at a command prompt and note its output. If you can't get that to work, find out from a local administrator or the documentation for your version of Perl about how to invoke *perldoc* or its equivalent. You'll need this for the next exercise anyway.
3. [6] Type in the second example program (from the previous section) and see what it prints. Hint: be careful to type those punctuation marks exactly as shown! Do you see how it changed the output of the command?

Chapter 2. Scalar Data

Perl's datatypes are simple. A *scalar* is a single thing. That's it. You may know the term *scalar* from physics or mathematics or some other discipline, but Perl's definition of the term is its own. It's so important that we'll say it again. A scalar is a single thing, and we use the word *thing* because we don't have a better way to describe what Perl considers a scalar.

A *scalar* is the simplest kind of data that Perl manipulates. Most scalars are either a number (like 255 or 3.25e20) or a string of characters (like `hello` or the Gettysburg Address). Although you may think of numbers and strings as very different things, Perl uses them nearly interchangeably.

If you have been using other programming languages, you're probably used to the idea of several different sorts of single items. C has `char`, `int`, and so on. Perl doesn't make distinctions among single things, which is something some people find hard to adjust to. However, as we'll see in this book, that allows us quite a bit of flexibility in dealing with data.

In this chapter, we show both scalar *data*, which are the values themselves, and scalar *variables*, which can store a scalar value. The distinction between these two is important. The value itself is fixed and we can't change it. We can, however, change what we store in a variable (hence its name). Sometimes programmers are a bit sloppy with this and simply say "scalar." We'll be a bit sloppy too, except when it matters. This will be more important in [Chapter 3](#).

Numbers

Although a scalar is most often either a number or a string, it's useful to look at numbers and strings separately for the moment. We'll cover numbers first, and then move on to strings.

All Numbers Have the Same Format Internally

Perl relies on the underlying C libraries for its numbers and uses a double-precision floating-point value to store the numbers. You don't have to know much about that, but it does mean Perl has some limitations in precision and magnitude of the numbers, which are related to how you compiled and installed the *perl* interpreter instead of a limitation of the language itself. Perl does this to be as fast as possible by using the optimizations of the local platform and libraries to do its math.

As you'll see in the next few paragraphs, you can specify both integers (whole numbers, like 255 or 2,001) and floating-point numbers (real numbers with decimal points, like 3.14159, or $1.35 \times 1,025$). But internally, Perl computes with double-precision floating-point values.

This means that there are no integer values internal to Perl—an integer constant in the program is treated as the equivalent floating-point value. In Perl, a number is just a number, unlike some other languages that ask you to decide what magnitude and type of number it is.

Integer Literals

A *literal* is how you represent a value in your source code. A literal is not the result of a calculation or an I/O operation; it's data that you type directly into your program. Integer literals are straightforward, as in:

```
0
2001
-40
137
61298040283768
```

That last one is a little hard to read. Perl allows you to add underscores for clarity within integer literals, so you can also write that number with embedded underscores to make it easier to read:

```
61_298_040_283_768
```

It's the same value; it merely looks different to us human beings. You might have thought that commas should be used for this purpose, but commas are already used for a more important purpose in Perl (as you'll see in [Chapter 3](#)). Even then, not everyone uses commas to separate numbers.

Nondecimal Integer Literals

Like many other programming languages, Perl allows you to specify numbers in ways other than base 10 (decimal). Octal (base 8) literals start with a leading 0 and use the digits from 0 to 7:

```
0377          # same as 255 decimal
```

Starting with v5.34, you can also start octal numbers with 0o, which brings octal numbers in line with the other bases you are about to see:

```
0o377         # same as 255 decimal
```

Hexadecimal (base 16) literals start with a leading 0x and use the digits 0 to 9 and the letters A through F (or a through f) to represent the values from 0 to 15:

```
0xff          # FF hex, also 255 decimal
```

Binary (base 2) literals start with a leading 0b and use only the digits 0 and 1:

```
0b11111111    # also 255 decimal
```

Although these values look different to us humans, all three are the same number to Perl. It makes no difference to Perl whether you write 0377, 0xFF, or 255, so choose the representation that makes the most sense for your task. Many shell commands in the Unix world assume octal numbers, for instance, so octal values make sense for the Perl equivalents you'll see in [Chapters 12](#) and [13](#).

NOTE

The “leading zero” indicator works only for literals—not for automatic string-to-number conversions, which you’ll see in [“Automatic Conversion Between Numbers and Strings”](#).

When a nondecimal literal is more than about four characters long, it may be hard to read, so underscores are handy:

```
0x1377_0B77
0x50_65_72_7C
```

Floating-Point Literals

Perl’s floating-point literals should look familiar to you. Numbers with and without decimal points are allowed (including an optional plus or minus prefix), as well as tacking on a power-of-10 indicator with E notation (also known as *exponential notation*).

For example:

```
1.25
255.000
255.0
7.25e45 # 7.25 times 10 to the 45th power (a big number)
-6.5e24 # negative 6.5 times 10 to the 24th
        # (a big negative number)
-12e-24 # negative 12 times 10 to the -24th
        # (a very small negative number)
-1.2E-23 # another way to say that the E may be uppercase
```

Perl v5.22 added hexadecimal floating-point literals. Instead of an e to mark the exponent, you use a p for the power-of-2 exponent. Just like the hexadecimal integers, these start with 0x:

```
0x1f.0p3
```

A hexadecimal floating-point literal is an exact representation of a number in the storage format that Perl uses. There is no ambiguity in its value. With

a decimal floating-point number, Perl (or C or anything else that uses doubles) can't represent the number exactly if it's not a power of two. Most people don't even notice this, and those who do see a very slight round-off error.

Numeric Operators

Operators are Perl's verbs. They decide how to treat the nouns. Perl provides the typical ordinary addition, subtraction, multiplication, and division operators. These numeric operators always treat their operands as numbers, and are denoted by symbolic characters:

```
2 + 3      # 2 plus 3, or 5
5.1 - 2.4  # 5.1 minus 2.4, or 2.7
3 * 12     # 3 times 12 = 36
14 / 2     # 14 divided by 2, or 7
10.2 / 0.3 # 10.2 divided by 0.3, or 34
10 / 3     # always floating-point divide, so 3.333333...
```

Perl's numeric operators return what you'd expect from doing the same operation on a calculator. Perl only has single values and it doesn't distinguish numbers that are integers, fractions, or floating-point numbers. This sometimes annoys people who are used to minutely specifying these in other languages. For instance, someone used to integer-only math might expect $10/3$ to be another integer (3).

Perl also supports a *modulus* operator (%). The value of the expression $10 \% 3$ is the remainder when 10 is divided by 3, which is 1. Both values are first reduced to their integer values, so $10.5 \% 3.2$ is computed as $10 \% 3$.

The result of the modulus operator when either or both numbers are negative can vary between Perl implementations because the underlying library does it differently because people disagree about rounding numbers. For $-10 \% 3$, is the remainder 2 because it's two places above -12 or -1 because it's one place from -9? It's best to avoid finding out accidentally.

Additionally, Perl provides the FORTRAN-like *exponentiation* operator, represented by the double asterisk. So, `2**3` is two to the third power, or eight. In addition, there are other numeric operators, which we'll introduce as we need them.

Strings

Strings are sequences of characters, such as `hello` or `☺★c~`. Strings may contain any combination of any characters. The shortest possible string has no characters and is called the *empty string*. The longest string fills all of your available memory (although you wouldn't be able to do much with that). This is in accordance with the principle of “no built-in limits” that Perl follows at every opportunity. Typical strings are printable sequences of letters, digits, punctuation, and whitespace. However, the ability to have any character in a string means you can create, scan, and manipulate raw binary data as strings—something with which many other utilities would have great difficulty. For example, you could update a graphical image or compiled program by reading it into a Perl string, making the change, and writing the result back out.

Perl has full support for Unicode, and your string can contain any of the valid Unicode characters. However, because of Perl's history, it doesn't automatically interpret your source as Unicode. If you want to use Unicode literally in your program, you need to add the `utf8` pragma. It's probably a good practice to always include this in your program unless you know why you wouldn't want to:

```
use utf8;
```

For the rest of this book, we assume you're using that pragma. In some cases it won't matter, but if you see characters outside the ASCII range in the source, you'll need it. Also, you should ensure that you save your files with the UTF-8 encoding. If you skipped our advice about Unicode from [Chapter 1](#), you might want to go through [Appendix C](#) to learn more.

NOTE

A *pragma* is something that tells the Perl compiler how to act.

Like numbers, strings have a literal representation, which is the way you represent the string in a Perl program. Literal strings come in two different flavors: *single-quoted string literals* and *double-quoted string literals*.

Single-Quoted String Literals

A *single-quoted string literal* is a sequence of characters enclosed in single quotes, the `'` character. The single quotes are not part of the string itself—they're just there to let Perl identify the beginning and end of the string:

```
'fred'      # those four characters: f, r, e, and d
'barney'    # those six characters
''          # the null string (no characters)
'%∞000%'   # Some "wide" Unicode characters
```

Any character other than a single quote or a backslash between the quote marks stands for itself inside a string. If you want a literal single quote or backslash inside your string, you need to *escape* it with a backslash:

```
'Don\'t let an apostrophe end this string prematurely!'
'the last character is a backslash: \\'
'\\'        # single quote followed by backslash
```

You can spread your string out over two (or more) lines. A newline between the single quotes is a newline in your string:

```
'hello
there'      # hello, newline, there (11 characters total)
```

Note that Perl does not interpret the `\n` within a single-quoted string as a newline but as the two characters backslash and `n`:

```
'hello\nthere'  # hello\nthere
```

Only when the backslash is followed by another backslash or a single quote does it have special meaning.

Double-Quoted String Literals

A *double-quoted string literal* is a sequence of characters, although this time enclosed in double quotes. But now the backslash takes on its full power to specify certain control characters, or even any character at all through octal and hex representations. Here are some double-quoted strings:

```
"barney"          # just the same as 'barney'
"hello world\n"   # hello world, and a newline
"The last character of this string is a quote mark: \""
"coke\tsprite"    # coke, a tab, and sprite
"\x{2668}"        # Unicode HOT SPRINGS character code point
"\N{SNOWMAN}"     # Unicode Snowman by name
```

Note that the double-quoted literal string "barney" means the same six-character string to Perl as does the single-quoted literal string 'barney'.

The backslash can precede many characters to mean something other than their literal representation (generally called a *backslash escape*). The nearly complete list of double-quoted string escapes is given in [Table 2-1](#).

Table 2-1. Double-quoted string backslash escapes

Construct	Meaning
<code>\007</code>	Any octal ASCII value (here, 007 = bell)
<code>\a</code>	Bell
<code>\b</code>	Backspace
<code>\cC</code>	A “control” character (here, Ctrl-C)
<code>\e</code>	Escape (ASCII escape character)
<code>\E</code>	End <code>\F</code> , <code>\L</code> , <code>\U</code> , or <code>\Q</code>
<code>\f</code>	Formfeed
<code>\F</code>	Unicode case-fold all following letters until <code>\E</code>
<code>\l</code>	Lowercase next letter
<code>\L</code>	Lowercase all following letters until <code>\E</code>
<code>\n</code>	Newline
<code>\N{CHARACTER NAME}</code>	Any Unicode code point, by name
<code>\Q</code>	Quote nonword characters by adding a backslash until <code>\E</code>
<code>\r</code>	Return
<code>\t</code>	Tab
<code>\u</code>	Uppercase next letter
<code>\U</code>	Uppercase all following letters until <code>\E</code>
<code>\x7f</code>	Any two-digit, hex ASCII value (here, 7f = delete)
<code>\x{2744}</code>	Any hex Unicode code point (here, U+2744 = snowflake)
<code>\\</code>	Backslash
<code>\“</code>	Double quote

Another feature of double-quoted strings is that they are *variable interpolated*, meaning that some variable names within the string are replaced with their current values when the strings are used. You haven't formally been introduced to what a variable looks like yet, so we'll get back to that later in this chapter.

String Operators

You can concatenate, or join, string values with the `.` operator. (Yes, that's a single period.) This does not alter either string, any more than `2+3` alters either 2 or 3. The resulting (longer) string is then available for further computation or assignment to a variable. For example:

```
"hello" . "world"          # same as "helloworld"
"hello" . ' ' . "world"    # same as 'hello world'
'hello world' . "\n"      # same as "hello world\n"
```

Note that you must explicitly use the concatenation operator, unlike in some other languages where you merely have to stick the two values next to each other.

A special string operator is the *string repetition* operator, consisting of the single lowercase letter `x`. This operator takes its left operand (a string) and makes as many concatenated copies of that string as indicated by its right operand (a number). For example:

```
"fred" x 3                # is "fredfredfred"
"barney" x (4+1)          # is "barney" x 5, or
"barneybarneybarneybarneybarney"
5 x 4.8                   # is really "5" x 4, which is "5555"
```

That last example is worth noting carefully. The string repetition operator wants a string for a left operand, so the number 5 is converted to the string `"5"` (using rules described in detail later), giving a one-character string. The `x` copies the new string four times, yielding the four-character string `5555`. Note that if you had reversed the order of the operands, as `4 x 5`,

you would have made five copies of the string 4, yielding 44444. This shows that string repetition is not commutative.

The copy count (the right operand) is first truncated to an integer value (4 . 8 becomes 4) before being used. A copy count of less than 1 results in an empty (zero-length) string.

Automatic Conversion Between Numbers and Strings

For the most part, Perl automatically converts between numbers and strings as needed. How does it know which it should use? It all depends on the operator that you apply to the scalar value. If an operator expects a number (like + does), Perl will see the value as a number. If an operator expects a string (like . does), Perl will see the value as a string. So, you don't need to worry about the difference between numbers and strings; just use the proper operators, and Perl will make it all work.

When you use a string value where an operator needs a number (say, for multiplication), Perl automatically converts the string to its equivalent numeric value, as if you had entered it as a decimal floating-point value. So "12" * "3" gives the value 36. Trailing nonnumerical stuff and leading whitespace are discarded, so "12fred34" * " 3" will also give 36 without any complaints (until you turn on warnings, which we'll show in a moment). At the extreme end of this, something that isn't a number at all converts to zero. This would happen if you used the string "fred" as a number.

The trick of using a leading zero to mean an octal value only works for literals and never for automatic conversion, which is always base 10:

```
0377      # that's octal for 255 decimal
'0377'    # that's 377 decimal
```

Later we'll show you `oct` to convert that string value as an octal number.

Likewise, if a numeric value is given where a string value is needed (say, for string concatenation), the numeric value is expanded into whatever

string would have been printed for that number. For example, if you want to concatenate the string `Z` followed by the result of 5 multiplied by 7, you can say this simply as:

```
"Z" . 5 * 7 # same as "Z" . 35, or "Z35"
```

In other words, you don't really have to worry about whether you have a number or a string (most of the time). Perl performs all the conversions for you. It even remembers what conversions it's already done so it can be faster next time.

Perl's Built-in Warnings

Perl can be told to warn you when it sees something suspicious going on in your program. With Perl 5.6 and later, you can turn on warnings with a pragma (but be careful because it won't work for people with ancient versions of Perl):

```
#!/usr/bin/perl
use warnings;
```

You can use the `-w` option on the command line, which turns on warnings everywhere in your program, including modules that you use but didn't write yourself, so you might see warnings from other people's code:

```
$ perl -w my_program
```

You can also specify the command-line switches on the shebang line:

```
#!/usr/bin/perl -w
```

Now, Perl will warn you if you use `'12fred34'` as if it were a number:

```
Argument "12fred34" isn't numeric
```

NOTE

The advantage of `warnings` over `-w` is that you only turn on warnings for the file in which you use the pragma, whereas `-w` turns on warnings for the entire program.

Perl still turns the nonnumeric `'12fred34'` into `12` using its normal rules even though you get the warning.

Of course, warnings are generally meant for programmers, not for end users. If the warning won't be seen by a programmer, it probably won't do you any good. And warnings won't change the behavior of your program, except that now it gripes once in a while. If you get a warning message you don't understand, you can get a longer description of the problem with the `diagnostics` pragma. The [perl_{diag} documentation](#) has both the short warning and the longer diagnostic description, and is the source of `diagnostics`'s helpfulness:

```
use diagnostics;
```

When you add the `use diagnostics` pragma to your program, it may seem to you that your program now pauses for a moment whenever you launch it. That's because your program has to do a lot of work (and gobble a chunk of memory) just in case you want to read the documentation as soon as Perl notices your mistakes, if any. This leads to a nifty optimization that can speed up your program's launch (and memory footprint) with no adverse impact on users: once you no longer need to read the documentation about the warning messages produced by your program, remove the `use diagnostics` pragma. It's even better if you fix your program to avoid causing the warnings. But it's sufficient merely to finish reading the output.

A further optimization can be had by using one of Perl's command-line options, `-M`, to load the pragma only when needed instead of editing the source code each time to enable and disable `diagnostics`:

```
$ perl -Mdiagnostics ./my_program
Argument "12fred34" isn't numeric in addition (+) at ./my_program
line 17 (#1)
    (W numeric) The indicated string was fed as an argument to
    an operator that expected a numeric value instead.  If you're
    fortunate the message will identify which operator was so
    unfortunate.
```

Note the (W numeric) in the message. The W says that the message is a warning and the numeric is the class of warning. In this case, you know to look for something dealing with a number.

As we run across situations in which Perl will usually be able to warn us about a mistake in our code, we'll point them out. But you shouldn't count on the text or behavior of any warning staying exactly the same in future Perl releases.

Interpreting Nondecimal Numerals

If you have a string that represents a number as another base, you can use the `hex()` or `oct()` function to interpret those numbers correctly.

Curiously, the `oct()` function is smart enough to recognize the correct base if you use prefix characters to specify hex or binary, but the only valid prefix for hex is `0x`:

```
hex('DEADBEEF')      # 3_735_928_559 decimal
hex('0xDEADBEEF')    # 3_735_928_559 decimal

oct('0377')          # 255 decimal
oct('0o377')         # 255 decimal, new in v5.34, saw leading 0o
oct('377')           # 255 decimal
oct('0xDEADBEEF')    # 3_735_928_559 decimal, saw leading 0x
oct('0b1101')        # 13 decimal, saw leading 0b
oct("0b$bits")       # convert $bits from binary
```

Those string representations are for us; the computer doesn't care how we want to think about the number. Specifying the same number in decimal or hexadecimal is all the same to Perl. As long as we correctly identify the *radix* of the number, Perl will translate it into its internal format.

Remember that Perl's automatic conversion only works for base-10 numbers, and that these routines only work on strings. Giving any of these a literal number, which Perl will have already converted to its internal format, will likely give the wrong results. Perl will turn the number back into a string, which it interprets as a hexadecimal number string, then into a Perl number:

```
hex( 10 )    # decimal 10, converted to "10", then decimal 16
hex( 0x10 )  # hex 10,      converted to "16", then decimal 22
```

We'll show you more about printing numbers in different bases in [Chapter 5](#).

Scalar Variables

A *variable* is a name for a container that holds one or more values. As you'll see, a scalar variable holds exactly one value, and in upcoming chapters you'll see other types of variables, such as arrays and hashes, that can hold many values. The name of the variable stays the same throughout your program, but the value or values in that variable can change over and over again.

A scalar variable holds a single scalar value, as you'd expect. Scalar variable names begin with a dollar sign, called the *sigil*, followed by a *Perl identifier*: a letter or underscore, and then possibly more letters, or digits, or underscores. Another way to think of it is that it's made up of alphanumerics and underscores, but can't start with a digit. Uppercase and lowercase letters are distinct: the variable `$Fred` is a different variable from `$fred`. And all of the letters, digits, and underscores are significant, so all of these refer to different variables:

```
$name
$Name
$NAME

$a_very_long_variable_that_ends_in_1
$a_very_long_variable_that_ends_in_2
```

```
$A_very_long_variable_that_ends_in_2  
$AVeryLongVariableThatEndsIn2
```

Perl doesn't restrict itself to ASCII for variable names, either. If you enable the `utf8` pragma, you can use a much wider range of alphabetic or numeric characters in your identifiers:

```
$résumé  
$coördinate
```

Perl uses the sigils to distinguish things that are variables from anything else that you might type in the program. You don't have to know the names of all the Perl functions and operators to choose your variable name.

Furthermore, Perl uses the sigil to denote what you're doing with that variable. The `$` sigil really means “single item” or “scalar.” Since a scalar variable is always a single item, it always gets the “single item” sigil. In [Chapter 3](#), you'll see the “single item” sigil used with another type of variable, the array. This is a very important concept in Perl. The sigil isn't telling you the variable type; it's telling you how you are accessing that variable.

Choosing Good Variable Names

You should generally select variable names that mean something regarding the purpose of the variable. For example, `$r` is probably not very descriptive, but `$line_length` is. If you are using a variable for only two or three lines close together, you might name it something simple, such as `$n`. A variable you use throughout a program should probably have a more descriptive name to not only remind you what it does, but let other people know what it does. Most of your program will make sense to you because you're the one who invented it. However, someone else isn't going to know why a name like `$srly` makes sense to you.

Similarly, properly placed underscores can make a name easier to read and understand, especially if your maintenance programmer has a different

spoken language background than you have. `$super_bowl` is a better name than `$superbowl`, for example, as that last one might look like `$superb_owl`. Does `$stopid` mean `$sto_pid` (storing a process ID of some kind?) or `$s_to_pid` (converting something to a process ID?) or `$stop_id` (the ID for some kind of “stop” object?) or is it just a stupid misspelling?

Most variable names in our Perl programs are all lowercase, like most of the ones you’ll see in this book. In a few special cases, uppercase letters are used. Using all caps (like `$ARGV`) generally indicates that there’s something special about that variable.

When a variable’s name has more than one word, some say `$underscores_are_cool`, while others say `$giveMeInitialCaps`. Just be consistent. You can name your variables with all uppercase, but you might end up using a special variable reserved for Perl. If you avoid all uppercase names, you won’t have that problem.

NOTE

The [perlvar documentation](#) lists all of Perl’s special variable names, and [perlstyle](#) has general programming style advice.

Of course, choosing good or poor names makes no difference to Perl. You *could* name your program’s three most important variables `$OOOOOOOOOO`, `$OOOOOOOOO`, and `$OOOOOOOOOO` and Perl wouldn’t be bothered—but in that case, please, don’t ask us to maintain your code.

Scalar Assignment

The most common operation on a scalar variable is *assignment*, which is the way to give a value to that variable. The Perl assignment operator is the equals sign (much like other languages), which takes a variable name on the left side and gives it the value of the expression on the right. For example:


```

$fred    = 17;           # give $fred the value of 17
$barney  = 'hello';      # give $barney the five-character string
                        'hello'
$barney  = $fred + 3;     # give $barney the current value of $fred
                        plus 3 (20)
$barney  = $barney * 2;   # $barney is now $barney multiplied by 2
                        (40)

```

Notice that last line uses the `$barney` variable twice: once to get its value (on the right side of the equals sign), and once to define where to put the computed expression (on the left side of the equals sign). This is legal, safe, and rather common. In fact, it's so common that you can write it using a convenient shorthand, as you'll see in the next section.

Compound Assignment Operators

Expressions like `$fred = $fred + 5` (where the same variable appears on both sides of an assignment) occur frequently enough that Perl (like C and Java) has a shorthand for the operation of altering a variable: the *compound assignment operator*. Nearly all binary operators that compute a value have a corresponding compound assignment form with an appended equals sign. For example, the following two lines are equivalent:

```

$fred  = $fred + 5; # without the compound assignment operator
$fred += 5;         # with the compound assignment operator

```

These are also equivalent:

```

$barney = $barney * 3;
$barney *= 3;

```

In each case, the operator alters the existing value of the variable in some way, rather than simply overwriting the value with the result of some new expression.

Another common assignment operator is made with the string concatenation operator (`.`). This gives us an append operator (`. =`):

```
$str = $str . " "; # append a space to $str
$str .= " ";      # same thing with compound assignment
```

Nearly all compound operators are valid this way. For example, a *raise to the power of operator* is written as `**=`. So, `$fred **= 3` means “raise the number in `$fred` to the third power, placing the result back in `$fred`.”

Output with print

It’s generally a good idea to have your program produce some output; otherwise, someone may think it didn’t do anything. The `print` operator makes this possible: it takes a scalar argument and puts it out without any embellishment onto standard output. Unless you’ve done something odd, this will be your terminal display. For example:

```
print "hello world\n"; # say hello world, followed by a newline

print "The answer is ";
print 6 * 7;
print ".\n";
```

You can give `print` a series of values separated by commas:

```
print "The answer is ", 6 * 7, ".\n";
```

This is really a *list*, but we haven’t talked about lists yet, so we’ll put that off for later.

Perl v5.10 adds a slightly better `print` that it calls `say`. It automatically puts a newline on the end for you:

```
use v5.10;
say "The answer is ", 6 * 7, '.';
```

If you can, use `say`. In this book, we tend to stick to `print` because we want most examples to work for the people stuck on v5.8.

Interpolation of Scalar Variables into Strings

When a string literal is double-quoted, it is subject to *variable interpolation* (besides being checked for backslash escapes). This means that a scalar variable name in the string is replaced with its current value. For example:

```
$meal    = "brontosaurus steak";  
$barney = "fred ate a $meal";      # $barney is now "fred ate a  
brontosaurus steak"  
$barney = 'fred ate a ' . $meal; # another way to write that
```

As you see on the last line, you can get the same results without the double quotes, but the double-quoted string is often the more convenient way to write it. Variable interpolation is also known as *double-quote interpolation* because it happens when double-quote marks (but not single quotes) are used. It happens for some other strings in Perl, which we'll mention as we get to them.

If the scalar variable has never been given a value, the empty string is used instead:

```
$barney = "fred ate a $meat"; # $barney is now "fred ate a "
```

You'll see more about this later in this chapter when we introduce the `undef` value.

Don't bother with interpolating if you have just the one lone variable:

```
print "$fred"; # unneeded quote marks  
print $fred;   # better style
```

There's nothing really wrong with putting quote marks around a lone variable, but you're not constructing a larger string, so you don't need the interpolation step.

To put a literal dollar sign into a double-quoted string, precede the dollar sign with a backslash, which turns off the dollar sign's special significance:

```
$fred = 'hello';  
print "The name is \$fred.\n";      # prints a dollar sign
```

Alternatively, you could avoid using double quotes around the problematic part of the string:

```
print 'The name is $fred' . "\n"; # so does this
```

The variable name will be the longest possible variable name that makes sense at that part of the string. This can be a problem if you want to follow the replaced value immediately with some constant text that begins with a letter, digit, or underscore.

As Perl scans for variable names, it considers those characters as additional name characters, which is not what you want. Perl provides a delimiter for the variable name in a manner similar to the shell. Simply enclose the name of the variable in a pair of curly braces. Or, you can end that part of the string and start another part of the string with a concatenation operator:

```
$what = "brontosaurus steak";  
$n = 3;  
print "fred ate $n $whats.\n";      # not the steaks, but the  
value of $whats  
print "fred ate $n ${what}s.\n";    # now uses $what  
print "fred ate $n $what" . "s.\n"; # another way to do it  
print 'fred ate ' . $n . ' ' . $what . "s.\n"; # an especially  
difficult way
```

NOTE

If you need a left square bracket or a left curly brace just after a scalar variable's name, precede it with a backslash. You may also do that if the variable's name is followed by an apostrophe or a pair of colons, or you could use the curly brace method.

Creating Characters by Code Point

Sometimes you want to create strings with characters that may not appear on your keyboard, such as *é*, *å*, *α*, or *ℵ*. How you get these characters into

your program depends on your system and the editor you're using, but sometimes, instead of typing them out, it's easier to create them by their code point with the `chr()` function:

```
$alef = chr( 0x05D0 );  
$alpha = chr( hex('03B1') );  
$omega = chr( 0x03C9 );
```

NOTE

We'll use "code point" throughout the book because we're assuming Unicode. In ASCII, we might have just said *ordinal value* to denote the numeric position in ASCII. To pick up anything you might have missed about Unicode, see [Appendix C](#).

You can go the other way with the `ord()` function, which turns a character into its code point:

```
$code_point = ord( 'α' );
```

You can interpolate these into double-quoted strings just like any other variable:

```
"$alpha$omega"
```

That might be more work than interpolating them directly by putting the hexadecimal representation in `\x{ }:`

```
"\x{03B1}\x{03C9}"
```

Operator Precedence and Associativity

Operator precedence determines which operations in a complex group happen first. For example, in the expression `2+3*4`, do you perform the addition first or the multiplication first? If you did the addition first, you'd get `5*4`, or 20. But if you did the multiplication first (as you were taught in math class), you'd get `2+12`, or 14. Fortunately, Perl chooses the common

mathematical definition, performing the multiplication first. Because of this, you say multiplication has a *higher* precedence than addition.

Parentheses have the highest precedence. Anything inside parentheses is completely computed before the operator outside the parentheses is applied (just like you learned in math class). So if you really want the addition before the multiplication, you can say $(2+3) * 4$, yielding 20. Also, if you wanted to demonstrate that multiplication is performed before addition, you could add a decorative but unnecessary set of parentheses, as in $2 + (3 * 4)$.

While precedence is simple for addition and multiplication, you start running into problems when faced with, say, string concatenation compared with exponentiation. The proper way to resolve this is to consult the official, accept-no-substitutes Perl operator precedence chart in the [perlop documentation](#), which we partially show in [Table 2-2](#).

Table 2-2. Associativity and precedence of operators (highest to lowest)

Associativity	Operators
left	parentheses and arguments to list operators
left	->
	++ -- (autoincrement and autodecrement)
right	**
right	\ ! ~ + - (unary operators)
left	= ~ ! ~
left	* / % x
left	+ - . (binary operators)
left	>> <<
	named unary operators (-X filetests, rand)
	< <= > >= lt le gt ge (the “unequal” ones)
	== != <=> eq ne cmp (the “equal” ones)
left	&
left	^
left	&&
left	//

right	? : (conditional operator)
right	= += -= . = (and similar assignment operators)
left	, =>

Associativity	Operators
	list operators (rightward)
right	not
left	and
left	or xor

In the chart, any given operator has higher precedence than all of the operators listed below it, and lower precedence than all of the operators listed above it. Operators at the same precedence level resolve according to rules of *associativity* instead.

Just like precedence, associativity resolves the order of operations when two operators of the same precedence compete for three operands:

```

4 ** 3 ** 2    # 4 ** (3 ** 2), or 4 ** 9 (right associative)
72 / 12 / 3    # (72 / 12) / 3, or 6/3, or 2 (left associative)
36 / 6 * 3     # (36/6)*3, or 18

```

In the first case, the `**` operator has right associativity, so the parentheses are implied on the right. Comparatively, the `*` and `/` operators have left associativity, yielding a set of implied parentheses on the left.

So should you just memorize the precedence chart? No! Nobody actually does that. Instead, just use parentheses when you don't remember the order of operations, or when you're too busy to look in the chart. After all, if you can't remember it without the parentheses, your maintenance programmer is going to have the same problem. So be nice to your maintenance programmer: you may be that person one day.

Comparison Operators

To compare numbers, Perl has logical comparison operators that may remind you of algebra: `<` `<=` `==` `>=` `>` `!=`. Each of these returns a *true* or *false* value. You'll find out more about those return values in the next section. Some of these may be different than what you'd use in other

languages. For example, `==` is used for equality, not a single `=`, because that's used for assignment. And `!=` is used for inequality testing because `<>` is used for another purpose in Perl. And you'll need `>=` and not `=>` for “greater than or equal to” because the latter is used for another purpose in Perl. In fact, nearly every sequence of punctuation is used for something in Perl. So, if you get writer's block, just let the cat walk across the keyboard, and debug the result.

To compare strings, Perl has an equivalent set of string comparison operators that look like funny little words: `lt`, `le`, `eq`, `ge`, `gt`, and `ne`. These compare two strings character by character to see whether they're the same, or whether one comes first in standard string sorting order. Note that the order of characters in ASCII or Unicode is not an order that might make sense to you. You'll see how to fix that in [Chapter 14](#).

The comparison operators (for both numbers and strings) are given in [Table 2-3](#).

Table 2-3. Numeric and string comparison operators

Comparison	Numeric	String
Equal	<code>==</code>	<code>eq</code>
Not equal	<code>!=</code>	<code>ne</code>
Less than	<code><</code>	<code>lt</code>
Greater than	<code>></code>	<code>gt</code>
Less than or equal to	<code><=</code>	<code>le</code>
Greater than or equal to	<code>>=</code>	<code>ge</code>

Here are some example expressions using these comparison operators:

```
35 != 30 + 5      # false
35 == 35.0        # true
'35' eq '35.0'    # false (comparing as strings)
'fred' lt 'barney' # false
```

```
'fred' lt 'free'      # true
'fred' eq "fred"     # true
'fred' eq 'Fred'     # false
' ' gt ''            # true
```

The if Control Structure

Once you can compare two values, you'll probably want your program to make decisions based on that comparison. Like all similar languages, Perl has an `if` control structure that only executes if its condition returns a true value:

```
if ($name gt 'fred') {
    print "'$name' comes after 'fred' in sorted order.\n";
}
```

If you need an alternative choice, the `else` keyword provides that as well:

```
if ($name gt 'fred') {
    print "'$name' comes after 'fred' in sorted order.\n";
} else {
    print "'$name' does not come after 'fred'.\n";
    print "Maybe it's the same string, in fact.\n";
}
```

You must have those block curly braces around the conditional code, unlike C (whether or not you know C). It's a good idea to indent the contents of the blocks of code as we show here; that makes it easier to see what's going on. If you're using a programmer's text editor (as we show in [Chapter 1](#)), it should do most of that work for you.

Boolean Values

You may actually use any scalar value as the conditional of the `if` control structure. That's handy if you want to store a true or false value in a variable, like this:

```
$is_bigger = $name gt 'fred';  
if ($is_bigger) { ... }
```

But how does Perl decide whether a given value is true or false? Perl doesn't have a separate Boolean datatype like some languages have. Instead, it uses a few simple rules:

- If the value is a number, 0 means false; all other numbers mean true.
- Otherwise, if the value is a string, the empty string (' ') and the string ' 0 ' mean false; all other strings mean true.
- If the variable doesn't have a value yet, it's false.

If you need to get the opposite of any Boolean value, use the unary *not* operator, `!`. If what follows is a true value, it returns false; if what follows is false, it returns true:

```
if (! $is_bigger) {  
    # Do something when $is_bigger is not true  
}
```

Here's a handy trick. Since Perl doesn't have a separate Boolean type, the `!` has to return some scalar to represent true and false. It turns out that 1 and 0 are good enough values, so some people like to normalize their data to just those values. To do that, they double up the `!` to turn true into false into true again (or the other way around):

```
$still_true  = !! 'Fred';  
$still_false = !! '0';
```

However, this idiom isn't documented to always return exactly the value 1 or 0, and we don't think that behavior will change anytime soon.

Getting User Input

At this point, you're probably wondering how to get a value from the keyboard into a Perl program. Here's the simplest way: use the line-input operator, `<STDIN>`.

NOTE

The `<STDIN>` is actually a line-input operator working on the filehandle `STDIN`, but we can't tell you about that until we get to filehandles (in [Chapter 5](#)).

Each time you use `<STDIN>` in a place where Perl expects a scalar value, Perl reads the next complete text line from *standard input* (up to and including the first newline), and uses that string as the value of `<STDIN>`. Standard input can mean many things, but unless you do something uncommon, it means the keyboard of the user who invoked your program (probably you). If there's nothing waiting for `<STDIN>` to read (typically the case, unless you type ahead a complete line), the Perl program will stop and wait for you to enter some characters followed by a newline (return).

The string value of `<STDIN>` usually has a newline character on the end of it, so you could do something like this:

```
$line = <STDIN>;
if ($line eq "\n") {
    print "That was just a blank line!\n";
} else {
    print "That line of input was: $line";
}
```

But in practice, you don't often want to keep the newline, so you need the `chomp()` operator.

The `chomp` Operator

The first time you read about the `chomp()` operator, it seems terribly overspecialized. It works on a variable. The variable has to hold a string,

and if the string ends in a newline character, `chomp()` removes that newline. That's (nearly) all it does. For example:

```
$text = "a line of text\n"; # Or the same thing from <STDIN>
chomp($text);               # Gets rid of the newline character
```

But it turns out to be so useful, you'll put it into nearly every program you write. As you see, it's the best way to remove a trailing newline from a string in a variable. In fact, there's an easier way to use `chomp()` because of a simple rule: anytime that you need a variable in Perl, you can use an assignment instead. First, Perl does the assignment. Then it uses the variable in whatever way you requested. So, the most common use of `chomp()` looks like this:

```
chomp($text = <STDIN>); # Read the text, without the newline
                        # character

$text = <STDIN>;        # Do the same thing...
chomp($text);           # ...but in two steps
```

At first glance, the combined `chomp()` may not seem to be the easy way, especially if it seems more complex! If you think of it as two operations—read a line, then `chomp()` it—it's more natural to write it as two statements. But if you think of it as one operation—read just the text, not the newline—it's more natural to write the one statement. And since most other Perl programmers are going to write it that way, you may as well get used to it now.

`chomp()` is actually a function. As a function, it has a return value, which is the number of characters removed. This number is hardly ever useful:

```
$food = <STDIN>;
$betty = chomp $food; # gets the value 1 - but you knew that!
```

As you see, you may write `chomp()` with or without the parentheses. This is another general rule in Perl: except in cases where it changes the meaning to remove them, parentheses are always optional.

If a string ends with two or more newlines, `chomp()` removes only one. If there's no newline, it does nothing, and returns zero. For the most part, you don't care what `chomp()` returns.

The while Control Structure

Like most algorithmic programming languages, Perl has a number of looping structures. The `while` loop repeats a block of code as long as a condition is true:

```
$count = 0;
while ($count < 10) {
    $count += 2;
    print "count is now $count\n"; # Gives values 2 4 6 8 10
}
```

As always in Perl, the truth value here works like the truth value in the `if` test. Also like the `if` control structure, the block curly braces are required. The conditional expression is evaluated before the first iteration, so the loop may be skipped completely if the condition is initially false.

NOTE

Eventually you'll create an infinite loop by accident. You can stop it in the same way you'd stop any other program. Often, typing Ctrl-C will stop a runaway program; check with your system's documentation to be sure.

The undef Value

What happens if you use a scalar variable before you give it a value? Nothing serious, and definitely nothing fatal. Variables have the special `undef` value before they are first assigned, which is just Perl's way of saying, "Nothing here to look at—move along, move along." If you try to use this "nothing" as a "numeric something," it acts like zero. If you try to

use it as a “string something,” it acts like the empty string. But `undef` is neither a number nor a string; it’s an entirely separate kind of scalar value.

Because `undef` automatically acts like zero when used as a number, it’s easy to make a numeric accumulator that starts out empty. You don’t do anything with `$sum` before you use it:

```
# Add up some odd numbers
$n = 1;
while ($n < 10) {
    $sum += $n;
    $n += 2; # On to the next odd number
}
print "The total was $sum.\n";
```

This works properly when `$sum` was `undef` before the loop started. The first time through the loop `$n` is 1, so the first line inside the loop adds 1 to `$sum`. That’s like adding 1 to a variable that already holds 0 (because you’re using `undef` as if it were a number). So now it has the value 1. After that, since it’s been initialized, addition works in the traditional way.

Similarly, you could have a string accumulator that starts out empty:

```
$string .= "more text\n";
```

If `$string` is `undef`, this will act as if it already held the empty string, putting `"more text\n"` into that variable. But if it already holds a string, the new text is simply appended.

Perl programmers frequently use a new variable in this way, letting it act as either zero or the empty string as needed.

Many operators return `undef` when the arguments are out of range or don’t make sense. If you don’t do anything special, you’ll get a zero or a null string without major consequences. In practice, this is hardly a problem. In fact, most programmers will rely on this behavior. But you should know that when warnings are turned on, Perl will typically warn about unusual uses of the undefined value, since that may indicate a bug. For example,

simply copying `undef` from one variable into another isn't a problem, but trying to print it generally causes a warning.

The defined Function

One operator that can return `undef` is the line-input operator, `<STDIN>`. Normally, it will return a line of text. But if there is no more input, such as at end-of-file, it returns `undef` to signal this. To tell whether a value is `undef` and not the empty string, use the `defined` function, which returns `false` for `undef` and `true` for everything else:

```
$next_line = <STDIN>;
if ( defined($next_line) ) {
    print "The input was $next_line";
} else {
    print "No input available!\n";
}
```

If you'd like to make your own `undef` values, you can use the obscurely named `undef` operator:

```
$next_line = undef; # As if it had never been touched
```

Exercises

See “[Answers to Chapter 2 Exercises](#)” for answers to these exercises:

1. [5] Write a program that computes the circumference of a circle with a radius of 12.5. Circumference is 2π times the radius (approximately 2 times 3.141592654). The answer you get should be about 78.5.
2. [4] Modify the program from the previous exercise to prompt for and accept a radius from the person running the program. So, if the user enters 12.5 for the radius, they should get the same number as in the previous exercise.

3. [4] Modify the program from the previous exercise so that, if the user enters a number less than zero, the reported circumference will be zero rather than negative.
4. [8] Write a program that prompts for and reads two numbers (on separate lines of input) and prints out the product of the two numbers multiplied together.
5. [8] Write a program that prompts for and reads a string and a number (on separate lines of input) and prints out the string the number of times indicated by the number on separate lines. (Hint: use the \times operator.) If the user enters “fred” and “3,” the output should be three lines, each saying “fred.” If the user enters “fred” and “299792,” there may be a lot of output.

Chapter 3. Lists and Arrays

If a scalar is the “singular” in Perl, as we described it at the beginning of [Chapter 2](#), the “plural” in Perl is represented by lists and arrays.

A *list* is an ordered collection of scalars. An *array* is a variable that contains a list. People tend to use the terms interchangeably, but there’s a big difference. The list is the data and the array is the variable that stores that data. You can have a list value that isn’t in an array, but every array variable holds a list (although that list may be empty). [Figure 3-1](#) represents a list, whether it’s stored in an array or not.

Since lists and arrays share many of the same operations, just like scalar values and variables do, we’ll treat them in parallel. Don’t forget their differences though.

VALUES	
ELEMENT NUMBERS (INDICES)	0 35
	1 12.4
	2 "hello"
	3 1.72e30
	4 "bye\n"

Figure 3-1. A list with five elements

Each *element* of an array or list is a separate scalar value. These values are ordered—that is, they have a particular sequence from the first to the last element. The elements of an array or a list are *indexed* by integers starting at zero and counting by ones, so the first element of any array or list is always element zero. This also means that the last index is one less than the number of items in the list.

Since each element is an independent scalar value, a list or array may hold numbers, strings, `undef` values, or any mixture of different scalar values. Nevertheless, it's common to have all elements of the same type, such as a list of book titles (all strings) or a list of cosines (all numbers).

Arrays and lists can have any number of elements. The smallest one has no elements, while the largest can fill all of available memory. Once again, this is in keeping with Perl's philosophy of "no unnecessary limits."

Accessing Elements of an Array

If you've used arrays in another language, you won't be surprised to find that Perl provides a way to *subscript* an array in order to refer to an element by a numeric index.

The array elements are numbered using sequential integers, beginning at 0 and increasing by 1 for each element, like this:

```
$fred[0] = "yabba";  
$fred[1] = "dabba";  
$fred[2] = "doo";
```

The array name itself (in this case, `fred`) is from a completely separate namespace than scalars use; you can have a scalar variable named `$fred` in the same program, and Perl will treat them as different things and won't be confused. (Your maintenance programmer might be confused, though, so don't capriciously make all of your variable names the same!)

You can use an array element like `$fred[2]` in (almost) every place where you could use any other scalar variable. For example, you can get the value from an array element or change that value by the same sort of expressions you used in [Chapter 2](#):

```
print $fred[0];  
$fred[2] = "diddley";  
$fred[1] .= "whatsis";
```

The subscript may be any expression that gives a numeric value. If it's not an integer already, Perl will automatically truncate it (not round!) to the whole number portion:

```
$number = 2.71828;  
print $fred[$number - 1]; # Same as printing $fred[1]
```

If the subscript indicates an element that would be beyond the end of the array, the corresponding value will be `undef`. This is just as with ordinary scalars; if you've never stored a value in the variable, it's `undef`:

```
$blank = $fred[ 142_857 ]; # unused array element gives undef
$blanc = $mel;             # unused scalar $mel also gives undef
```

Special Array Indices

If you assign to an array element that is beyond the end of the array, the array is automatically extended as needed—there’s no limit on its length, as long as there’s available memory for Perl to use. If Perl needs to create the intervening elements, it creates them as `undef` values:

```
$rocks[0]  = 'bedrock';      # One element...
$rocks[1]  = 'slate';        # another...
$rocks[2]  = 'lava';         # and another...
$rocks[3]  = 'crushed rock'; # and another...
$rocks[99] = 'schist';       # now there are 95 undef elements
```

Sometimes you need to find out the last element index in an array. For the array of `rocks`, the last element index is `$#rocks`. That’s not the same as the number of elements, though, because there’s an element number zero:

```
$end = $#rocks;          # 99, which is the last
                        # element's index
$number_of_rocks = $end + 1; # OK, but you'll see a better
                        # way later
$rocks[ $#rocks ] = 'hard rock'; # the last rock
```

Using the `$#name` value as an index, like that last example, happens often enough that Larry has provided a shortcut: negative array indices count from the end of the array. But don’t get the idea that these indices “wrap around.” If you have three elements in the array, the valid negative indices are `-1` (the last element), `-2` (the middle element), and `-3` (the first element). If you try `-4` and beyond, you just get `undef`. In the real world, nobody seems to use any of these except `-1`, though:

```
$rocks[ -1 ]  = 'hard rock'; # easier way to do that last
                        # example
$dead_rock    = $rocks[-100]; # gets 'bedrock'
$rocks[ -200 ] = 'crystal';   # fatal error!
```

List Literals

A *list literal* (the way you represent a list value within your program) is a list of comma-separated values enclosed in parentheses. These values form the elements of the list. For example:

```
(1, 2, 3)      # list of three values 1, 2, and 3
(1, 2, 3,)     # the same three values (the trailing comma is
ignored)
("fred", 4.5)  # two values, "fred" and 4.5
( )           # empty list - zero elements
```

You don't have to type out every value if they are in sequence. The *.. range operator* creates a list of values by counting from the left scalar up to the right scalar by ones. For example:

```
(1..100)       # list of 100 integers
(1..5)         # same as (1, 2, 3, 4, 5)
(1.7..5.7)     # same thing; both values are truncated
(0, 2..6, 10, 12) # same as (0, 2, 3, 4, 5, 6, 10, 12)
```

The range operator only counts up, so this won't work and you'll get the empty list:

```
(5..1)         # empty list; .. only counts "uphill"
```

The elements of a list literal are not necessarily constants; they can be expressions that will be newly evaluated each time the literal is used. For example:

```
($m, 17)       # two values: the current value of $m, and 17
($m+$o, $p+$q) # two values
($m..$n)       # range determined by current values of $m and $n
(0..$#rocks)   # the indices of the rocks array from the previous
section
```

The qw Shortcut

A list may have any scalar values, like this typical list of strings:

```
("fred", "barney", "betty", "wilma", "dino")
```

It turns out that lists of simple words (like the previous example) are frequently needed in Perl programs. The `qw` shortcut makes it easy to generate them without typing a lot of extra quote marks:

```
qw( fred barney betty wilma dino ) # same as earlier, but less
typing
```

`qw` stands for “quoted words” or “quoted by whitespace,” depending on whom you ask. Either way, Perl treats it like a single-quoted string (so, you can’t use `\n` or `$fred` inside a `qw` list as you would in a double-quoted string). The whitespace (characters like spaces, tabs, and newlines) disappear and whatever is left becomes the list of items. Since whitespace is insignificant, here’s another (but unusual) way to write that same list:

```
qw(fred
    barney      betty
    wilma dino) # same as before, but pretty strange whitespace
```

Since `qw` is a form of quoting, though, you can’t put comments inside a `qw` list. Some people like to format their lists with one element per line, which makes it easy to read as a column:

```
qw(
    fred
    barney
    betty
    wilma
    dino
)
```

The previous two examples used parentheses, but Perl lets you choose any punctuation character as the delimiter. Here are some of the common ones:

```
qw! fred barney betty wilma dino !
qw/ fred barney betty wilma dino /
qw# fred barney betty wilma dino #    # like in a comment!
```

Sometimes the two delimiters can be different. If the opening delimiter is one of those “left” characters, the corresponding “right” character is the proper closing delimiter:

```
qw( fred barney betty wilma dino )
qw{ fred barney betty wilma dino }
qw[ fred barney betty wilma dino ]
qw< fred barney betty wilma dino >
```

If you need to include the closing delimiter *within* the string as one of the characters, you probably picked the wrong delimiter. But even if you can’t or don’t want to change the delimiter, you can still include the character using the backslash:

```
qw! yahoo\! google ask msn ! # include yahoo! as an element
```

As in single-quoted strings, two consecutive backslashes contribute one single backslash to the item:

```
qw( This as a \\ real backslash );
```

Now, although the Perl motto is “There’s More Than One Way To Do It,” you may wonder why anyone would need all of those different ways! Well, you’ll see later that there are other kinds of quoting where Perl uses this same rule, and it can come in handy in many of those. But even here, it could be useful if you need a list of Unix filenames:

```
qw{
    /usr/dict/words
    /home/rootbeer/.ispell_english
}
```

That list would be quite inconvenient to read, write, and maintain if you could only use the / as a delimiter.

List Assignment

In much the same way as you can assign scalar values to variables, you can assign list values to variables:

```
($fred, $barney, $dino) = ("flintstone", "rubble", undef);
```

All three variables in the list on the left get new values, just as if you did three separate assignments. Since the list on the right side is built up before the assignment starts, this makes it easy to swap two variables' values in Perl:

```
($fred, $barney) = ($barney, $fred); # swap those values
($betty[0], $betty[1]) = ($betty[1], $betty[0]);
```

But what happens if the number of variables (on the left side of the equals sign) isn't the same as the number of values (from the right side)? In a list assignment, extra values are silently ignored—Perl figures that if you wanted those values stored somewhere, you would have told it where to store them. Alternatively, if you have too many variables, the extras get the value `undef` (or the empty list, as you'll see in a moment):

```
($fred, $barney) = qw< flintstone rubble slate granite >; # two
ignored items
($wilma, $dino) = qw[flintstone]; # $dino
gets undef
```

Now that you can assign lists, you *could* build up an array of strings with a line of code like this:

```
($rocks[0], $rocks[1], $rocks[2], $rocks[3]) = qw/talc mica
feldspar quartz/;
```

But when you wish to refer to an entire array, Perl has a simpler notation. Use the at sign (`@`) before the name of the array (and no index brackets after it) to refer to the entire array at once. You can read this as “all of the,” so `@rocks` is “all of the rocks.” This works on either side of the assignment operator:

```

@rocks  = qw/ bedrock slate lava /;
@tiny   = ( );                               # the empty list
@giant  = 1..1e5;                             # a list with 100,000
elements
@stuff  = (@giant, undef, @giant);             # a list with 200,001
elements
$dino   = "granite";
@quarry = (@rocks, "crushed rock", @tiny, $dino);

```

That last assignment gives @quarry the five-element list (bedrock, slate, lava, crushed rock, granite), since @tiny contributes zero elements to the list. In particular, it doesn't add an undef item to the list—but you could do that explicitly, as we did with @stuff earlier. It's also worth noting that an array name expands to the list it contains. An array doesn't become an element in the list, because these arrays can contain only scalars, not other arrays. The value of an array variable that has not yet been assigned is (), the empty list. Just as new, empty scalars start out with undef, new, empty arrays start out with the empty list.

NOTE

In *Intermediate Perl*, we cover references, which lets you make what are informally called “lists of lists,” among other interesting and useful structures. The [perldsc documentation](#) is worth a read.

When you copy an array to another array, it's still a list assignment. The lists are simply stored in arrays. For example:

```
@copy = @quarry; # copy a list from one array to another
```

The pop and push Operators

You *could* add new items to the end of an array by simply storing them as elements with new, larger indices.

One common use of an array is as a *stack* of information, where you add new values to and remove old values from the righthand side of the list. The

right-hand side is the end with the “last” items in the array, the end with the highest index values. These operations occur often enough to have their own special functions. Think of this like a stack of plates. You take a plate off the top of the stack and put plates on top of the stack (if you’re like most people).

The `pop` operator takes the last element off of an array and returns it:

```
@array = 5..9;
$fred  = pop(@array); # $fred gets 9, @array now has (5, 6, 7, 8)
$barney = pop @array; # $barney gets 8, @array now has (5, 6, 7)
pop @array;           # @array now has (5, 6). (The 7 is discarded.)
```

That last example uses `pop` in a *void context*, which is merely a fancy way of saying the return value isn’t going anywhere. There’s nothing wrong with using `pop` in this way, if that’s what you want.

If the array is empty, `pop` leaves it alone (since there is no element to remove) and returns `undef`.

You may have noticed that you can use `pop` with or without parentheses. This is a general rule in Perl: as long as you don’t change the meaning by removing the parentheses, they’re optional. The converse operation is `push`, which adds an element (or a list of elements) to the end of an array:

```
push(@array, 0);      # @array now has (5, 6, 0)
push @array, 8;       # @array now has (5, 6, 0, 8)
push @array, 1..10;    # @array now has those 10 new elements
@others = qw/ 9 0 2 1 0 /;
push @array, @others; # @array now has those five new elements
(19 total)
```

Note that the first argument to `push` or the only argument for `pop` must be an array variable—pushing and popping would not make sense on a literal list.

You can use a third argument to specify a length. Read that sentence again because many people assume that the third argument is an ending position, but no, it's a length. That way, you can remove elements from the middle and leave some at the end:

```
@array = qw( pebbles dino fred barney betty );
@removed = splice @array, 1, 2; # remove dino, fred
                                # @removed is qw(dino fred)
                                # @array is qw(pebbles barney
betty)
```

The fourth argument is a replacement list. At the same time that you take some elements out, you can put others in. The replacement list does not need to be the same size as the slice that you are removing:

```
@array = qw( pebbles dino fred barney betty );
@removed = splice @array, 1, 2, qw(wilma); # remove dino, fred
                                # @removed is qw(dino fred)
                                # @array is qw(pebbles wilma
                                #               barney betty)
```

You don't have to remove any elements. If you specify a length of 0, you remove no elements but still insert the "replacement" list:

```
@array = qw( pebbles dino fred barney betty );
@removed = splice @array, 1, 0, qw(wilma); # remove nothing
                                # @removed is qw()
                                # @array is qw(pebbles wilma dino
                                #               fred barney
betty)
```

Notice that `wilma` shows up before `dino`. Perl inserted the replacement list starting at index 1 and moved everything else over.

`splice` might not seem like a big deal to you, but this is a hard thing to do in some languages, and many people developed complicated techniques, such as linked lists, that take a lot of programmer attention to get right. Perl handles those details for you.

Interpolating Arrays into Strings

As with scalars, you can interpolate array values into a double-quoted string. Perl expands the array and automatically adds spaces between the elements, putting the whole result in the string upon interpolation:

```
@rocks = qw{ flintstone slate rubble };  
print "quartz @rocks limestone\n"; # prints five rocks separated  
by spaces
```

There are no extra spaces added before or after an interpolated array; if you want those, you'll have to put them in yourself:

```
print "Three rocks are: @rocks.\n";  
print "There's nothing in the parens (@empty) here.\n";
```

If you forget that arrays interpolate like this, you'll be surprised when you put an email address into a double-quoted string:

```
$email = "fred@bedrock.edu"; # WRONG! Tries to interpolate  
@bedrock
```

Although you probably intended to have an email address, Perl sees the array named `@bedrock` and tries to interpolate it. Depending on your version of Perl, you'll probably just get a warning:

```
Possible unintended interpolation of @bedrock
```

To get around this problem, you either escape the `@` in a double-quoted string or use a single-quoted string:

```
$email = "fred\@bedrock.edu"; # Correct  
$email = 'fred@bedrock.edu'; # Another way to do that
```

A single element of an array interpolates into its value, just as you'd expect from a scalar variable:

```
@fred = qw(hello dolly);
$y = 2;
$x = "This is $fred[1]'s place";    # "This is dolly's place"
$x = "This is $fred[$y-1]'s place"; # same thing
```

Note that the index expression evaluates as an ordinary expression, as if it were outside a string. It is *not* variable-interpolated first. In other words, if `$y` contains the string `"2*4"`, we're still talking about element 1, not element 7, because the string `"2*4"` as a number (the value of `$y` used in a numeric expression) is just plain 2.

If you want to follow a simple scalar variable with a left square bracket, you need to delimit the square bracket so that it isn't considered part of an array reference, as follows:

```
@fred = qw(eating rocks is wrong);
$fred = "right";                # we are trying to say "this is
right[3]"
print "this is $fred[3]\n";      # prints "wrong" using $fred[3]
print "this is ${fred}[3]\n";    # prints "right" (protected by
braces)
print "this is $fred"."[3]\n";   # right again (different string)
print "this is $fred\[3]\n";     # right again (backslash hides it)
```

The foreach Control Structure

It's handy to be able to process an entire array or list, so Perl provides a control structure to do just that. The `foreach` loop steps through a list of values, executing one iteration (time through the loop) for each value:

```
foreach $rock (qw/ bedrock slate lava /) {
    print "One rock is $rock.\n";    # Prints names of three rocks
}
```

The control variable (`$rock` in that example) takes on a new value from the list for each iteration. The first time through the loop, it's `"bedrock"`; the third time, it's `"lava"`.

The control variable is not a copy of the list element—it actually *is* the list element. That is, if you modify the control variable inside the loop, you modify the element itself, as shown in the following code snippet. This is useful, and supported, but it would surprise you if you weren't expecting it:

```
@rocks = qw/ bedrock slate lava /;
foreach $rock (@rocks) {
    $rock = "\t$rock";          # put a tab in front of each element
    of @rocks
    $rock .= "\n";              # put a newline on the end of each
}
print "The rocks are:\n", @rocks; # Each one is indented, on its
own line
```

What is the value of the control variable after the loop has finished? It's the same as it was before the loop started. Perl automatically saves and restores the value of the control variable of a `foreach` loop. While the loop is running, there's no way to access or alter that saved value. So after the loop is done, the variable has the value it had before the loop, or `undef` if it hadn't had a value:

```
$rock = 'shale';
@rocks = qw/ bedrock slate lava /;

foreach $rock (@rocks) {
    ...
}

print "rock is still $rock\n"; # 'rock is still shale'
```

That means that if you want to name your loop control variable `$rock`, you don't have to worry that maybe you've already used that name for another variable. After we introduce subroutines to you in [Chapter 4](#), we'll show you a better way to handle that.

NOTE

That triple dot (. . .) is actually valid Perl. It was added in v5.12 as a placeholder. It compiles but is a fatal error if the program encounters it. There's a range operator that looks the same, but since this use stands alone, it's the *yada yada* operator.

Perl's Favorite Default: \$ _

If you omit the control variable from the beginning of the `foreach` loop, Perl uses its favorite default variable, `$ _`. This is (mostly) just like any other scalar variable, except for its unusual name. For example:

```
foreach (1..10) { # Uses $ _ by default
    print "I can count to $ _!\n";
}
```

Although this isn't Perl's only default by a long shot, it's Perl's most common default. You'll see many other cases in which Perl will automatically use `$ _` when you don't tell it to use some other variable or value, thereby saving the programmer from the heavy labor of having to think up and type a new variable name. So as not to keep you in suspense, one of those cases is `print`, which will output `$ _` if given no other argument:

```
$ _ = "Yabba dabba doo\n";
print; # prints $ _ by default
```

The reverse Operator

The `reverse` operator takes a list of values (which may come from an array) and returns the list in the opposite order. So if you were disappointed that the range operator only counts upward, this is the way to fix it:

```
@fred    = 6..10;
@barney = reverse(@fred); # gets 10, 9, 8, 7, 6
@wilma  = reverse 6..10;  # gets the same thing, without the
other array
```

```
@fred = reverse @fred; # puts the result back into the
original array
```

The last line is noteworthy because it uses `@fred` twice. Perl always calculates the value being assigned (on the right) before it begins the actual assignment.

Remember that `reverse` returns the reversed list; it doesn't affect its arguments. If the return value isn't assigned anywhere, it's useless:

```
reverse @fred; # WRONG - doesn't change @fred
@fred = reverse @fred; # that's better
```

The sort Operator

The `sort` operator takes a list of values (which may come from an array) and sorts them in the internal character ordering. For strings, that would be in code point order. In pre-Unicode Perls, the sort order was based on ASCII, but Unicode maintains that same order as well as defining the order of many more characters. So, the code point order is a strange place where all of the capital letters come before all of the lowercase letters, where the numbers come before the letters, and the punctuation marks—well, those are here, there, and everywhere. But sorting in that order is just the *default* behavior; you'll see in [Chapter 14](#) how to sort in whatever order you'd like. The `sort` operator takes an input list, sorts it, and outputs a new list:

```
@rocks = qw/ bedrock slate rubble granite /;
@sorted = sort(@rocks); # gets bedrock, granite, rubble,
slate
@back = reverse sort @rocks; # these go from slate to bedrock
@rocks = sort @rocks; # puts sorted result back into
@rocks
@numbers = sort 97..102; # gets 100, 101, 102, 97, 98, 99
```

As you can see from that last example, sorting numbers as if they were strings may not give useful results. But, of course, any string that starts with 1 has to sort before any string that starts with 9, according to the default sorting rules. And like what happened with `reverse`, the arguments

themselves aren't affected. If you want to sort an array, you must store the result back into that array:

```
sort @rocks;           # WRONG, doesn't modify @rocks
@rocks = sort @rocks; # Now the rock collection is in order
```

The each Operator

Starting with v5.12, you can use the `each` operator on arrays. Before that version, you could only use `each` with hashes, but we don't show you those until [Chapter 6](#). Every time you call `each` on an array, it returns two values for the next element in the array—the index of the value and the value itself:

```
require v5.12;

@rocks = qw/ bedrock slate rubble granite /;
while( ( $index, $value ) = each @rocks ) {
    print "$index: $value\n";
}
```

NOTE

We used `require` here because a use `v5.12` would turn on “strict” mode. We don't tell you how to fix that until [Chapter 4](#), so we punt here. You'll be fine after the next chapter.

If you wanted to do this without `each`, you'd have to iterate through all of the indices of the array and use the index to get the value:

```
@rocks = qw/ bedrock slate rubble granite /;
foreach $index ( 0 .. $#rocks ) {
    print "$index: $rocks[$index]\n";
}
```

Depending on your task, one or the other may be more convenient for you.

Scalar and List Context

This is the most important section in this chapter. In fact, it's the most important section in the entire book. It wouldn't be an exaggeration to say that your entire career in using Perl will depend on understanding this section. So if you've gotten away with skimming the text up to this point, this is where you should really pay attention.

That's not to say that this section is in any way difficult to understand. It's actually a simple idea: a given expression may mean different things depending upon where it appears and how you use it. This is nothing new to you; it happens all the time in natural languages. For example, in English, suppose someone asked you what the word "flies" means. It has different meanings depending on how it's used. You can't identify the meaning until you know the *context*.

The context refers to how you use an expression. You've actually already seen some contextual operations with numbers and strings. When you do numbery sorts of things, you get numeric results. When you do stringy sorts of things, you get string results. And it's the operator that decides what you are doing, not the values. The `*` in `2*3` is numeric multiplication, while the `x` in `2x3` is string replication. The first gives you 6 while the second gives you 222. That's context at work for you.

As Perl is parsing your expressions, it always expects either a scalar value or a list value (or void, which we don't cover in this book). What Perl expects is called the context of the expression:

```
42 + something # The something must be a scalar
sort something # The something must be a list
```

This is like spoken languages. If we make a grammatical mistake, you notice it right away because you expect certain words in certain places. Eventually, you'll read Perl this way too, but at first you have to think about it.

Even if *something* is the exact same sequence of characters, in one case it may give a single, scalar value, while in the other, it may give a list. Expressions in Perl always return the appropriate value for their context. For example, how about the “name” of an array. In a list context, it gives the list of elements. But in a scalar context, it returns the number of elements in the array:

```
@people = qw( fred barney betty );
@sorted = sort @people; # list context: barney, betty, fred
$number = 42 + @people; # scalar context: 42 + 3 gives 45
```

Even ordinary assignment (to a scalar or a list) causes different contexts:

```
@list = @people; # a list of three people
$n = @people;    # the number 3
```

But please don’t jump to the conclusion that scalar context always gives the number of elements that would have been returned in list context. Most list-producing expressions return something *much* more interesting.

Any expression can produce a list or a scalar depending on context. So when we say “list-producing expressions,” we mean those that are typically used in a list context and therefore might surprise you when they’re used unexpectedly in a scalar context (like `reverse` or `@fred`).

Not only that, but you can’t make any general rules to apply what you know about some expressions to others. Each expression can make up its own rules. Or, really, follow the overall rule that isn’t very helpful to you: do the thing that makes the most sense for that context. Perl is very much a language that tries to do the most common, mostly right thing for you.

Using List-Producing Expressions in Scalar Context

There are many expressions that you will typically use to produce a list. If you use one in a scalar context, what do you get? See what the author of that operation says about it. Usually that person is Larry, and usually the documentation gives the whole story. In fact, a big part of learning Perl is

actually learning how Larry thinks. Therefore, once you can think like Larry does, you know what Perl should do. But while you're learning, you'll probably need to look into the documentation.

Some expressions don't have a scalar-context value at all. For example, what should `sort` return in a scalar context? You wouldn't need to sort a list to count its elements, so until someone implements something else, `sort` in a scalar context always returns `undef`.

Another example is `reverse`. In a list context, it gives a reversed list. In a scalar context, it returns a reversed string (or reversing the result of concatenating all the strings of a list, if given one):

```
@backwards = reverse qw/ yabba dabba doo /;
# gives doo, dabba, yabba
$backwards = reverse qw/ yabba dabba doo /;
# gives oodabbadabbay
```

At first, it's not always obvious whether an expression is being used in a scalar or a list context. But trust us, it *will* become second nature for you eventually.

Here are some common contexts to start you off:

```
$fred = something;           # scalar context
@pebbles = something;        # list context
($wilma, $betty) = something; # list context
($dino) = something;         # still list context!
```

Don't be fooled by the one-element list; that last one is a list context, not a scalar one. The parentheses are significant here, making the fourth of those different than the first. If you assign to a list (no matter the number of elements), it's a list context. If you assign to an array, it's a list context.

Here are some other expressions you've seen, and the contexts they provide. First, some that provide scalar context to *something*:

```
$fred = something;
$fred[3] = something;
```

```
123 + something
something + 654
if (something) { ... }
while (something) { ... }
$fred[something] = something;
```

And here are some that provide a list context:

```
@fred = something;
($fred, $barney) = something;
($fred) = something;
push @fred, something;
foreach $fred (something) { ... }
sort something
reverse something
print something
```

Using Scalar-Producing Expressions in List Context

Going this direction is straightforward: if an expression doesn't normally have a list value, the scalar value is automatically promoted to make a one-element list:

```
@fred = 6 * 7; # gets the one-element list (42)
@barney = "hello" . ' ' . "world";
```

Well, there's one possible catch. Since `undef` is a scalar value, assigning `undef` to an array doesn't clear the array. The better way to do that is to assign an empty list:

```
@wilma = undef; # OOPS! Gets the one-element list (undef)
# which is not the same as this:
@betty = ( ); # A correct way to empty an array
```

Forcing Scalar Context

On occasion, you may need to force scalar context where Perl is expecting a list. In that case, you can use the fake function `scalar`. It's not a true function because it just tells Perl to provide a scalar context:

```
@rocks = qw( talc quartz jade obsidian );
print "How many rocks do you have?\n";
print "I have ", @rocks, " rocks!\n";           # WRONG, prints
names of rocks
print "I have ", scalar @rocks, " rocks!\n"; # Correct, gives a
number
```

Oddly enough, there's no corresponding function to force list context. It turns out you almost never need it. Trust us on this too.

<STDIN> in List Context

One previously seen operator that returns a different value in an array context is the line-input operator, <STDIN>. As we described earlier, <STDIN> returns the next line of input in a scalar context. Now, in list context, this operator returns *all* of the remaining lines up to the end-of-file. It returns each line as a separate element of the list. For example:

```
@lines = <STDIN>; # read standard input in list context
```

When the input is coming from a file, this will read the rest of the file. But how can there be an end-of-file when the input comes from the keyboard? On Unix and similar systems, including Linux and macOS, you'll normally type a Ctrl-D to indicate to the system that there's no more input; the special character itself is never seen by Perl, even though it may be echoed to the screen. On DOS/Windows systems, use Ctrl+Z instead. You'll need to check the documentation for your system or ask your local expert if it's different from these.

NOTE

There's a bug affecting some ports of Perl for DOS/Windows where the first line of output to the terminal following the use of Ctrl+Z is obscured. On these systems, you can work around this problem by simply printing a blank line (" \n ") after reading the input.

If the person running the program types three lines, then presses the proper keys needed to indicate end-of-file, the array ends up with three elements. Each element will be a string that ends in a newline, corresponding to the three newline-terminated lines entered.

Wouldn't it be nice if, having read those lines, you could `chomp` the newlines all at once? It turns out that if you give `chomp` an array holding a list of lines, it will remove the newlines from each item in the list. For example:

```
@lines = <STDIN>; # Read all the lines
chomp(@lines);    # discard all the newline characters
```

But the more common way to write that is with code similar to what you used earlier:

```
chomp(@lines = <STDIN>); # Read the lines, not the newlines
```

Although you're welcome to write your code either way in the privacy of your own cubicle, most Perl programmers will expect the second, more compact, notation.

It may be obvious to you (but it's not obvious to everyone) that once these lines of input have been read, they can't be reread. Once you've reached end-of-file, there's no more input out there to read.

And what happens if the input is coming from a 4 TB logfile? The line-input operator reads all of the lines, gobbling up lots of memory. Perl tries not to limit you in what you can do, but the other users of your system (not to mention your system administrator) are likely to object. If the input data is large, you should generally find a way to deal with it without reading it all into memory at once.

Exercises

See “[Answers to Chapter 3 Exercises](#)” for answers to these exercises:

1. [6] Write a program that reads a list of strings on separate lines until end-of-input and prints out the list in reverse order. If the input comes from the keyboard, you'll probably need to signal the end of the input by pressing Ctrl-D in Unix or Ctrl+Z on Windows.
2. [12] Write a program that reads a list of numbers (on separate lines) until end-of-input and then prints for each number the corresponding person's name from the following list. (Hardcode this list of names into your program. That is, it should appear in your program's source code.) For example, if the input numbers were 1, 2, 4, and 2, the output names would be fred, betty, dino, and betty:

```
fred betty barney dino wilma pebbles bamm-bamm
```

3. [8] Write a program that reads a list of strings (on separate lines) until end-of-input. Then it should print the strings in code point order. That is, if you enter the strings fred, barney, wilma, betty, the output should show barney betty fred wilma. Are all of the strings on one line in the output or on separate lines? Could you make the output appear in either style?

Chapter 4. Subroutines

You've already seen and used some of the built-in system functions, such as `chomp`, `reverse`, `print`, and so on. But, as other languages do, Perl has the ability to make *subroutines*, which are user-defined functions. These let you recycle one chunk of code many times in one program. The name of a subroutine is another Perl identifier (letters, digits, and underscores, but they can't start with a digit) with a sometimes-optional ampersand (&) in front. There's a rule about when you can omit the ampersand and when you cannot; you'll see that rule by the end of the chapter. For now, just use it every time it's not forbidden, which is always a safe rule. We'll tell you every place where it's forbidden, of course.

The subroutine name comes from a separate namespace, so Perl won't be confused if you have a subroutine called `&fred` and a scalar called `$fred` in the same program—although there's no reason to do that under normal circumstances.

Defining a Subroutine

To define your own subroutine, use the keyword `sub`, the name of the subroutine (without the ampersand), then the block of code in curly braces, which makes up the *body* of the subroutine. Something like this:

```
sub marine {  
    $n += 1; # Global variable $n  
    print "Hello, sailor number $n!\n";  
}
```

You may put your subroutine definitions anywhere in your program text, but programmers who come from a background of languages like C or Pascal like to put them at the start of the file. Others may prefer to put them at the end of the file so that the main part of the program appears at the

beginning. It's up to you. In any case, you don't normally need any kind of forward declaration. If you have two subroutine definitions with the same name, the later one overwrites the earlier one. Although, if you have warnings enabled, Perl will tell you when you do that. It's generally considered bad form, or the sign of a confused maintenance programmer.

NOTE

We don't talk about subroutines of the same name in different packages until *Intermediate Perl*.

As you may have noticed in the previous example, you may use any global variables within the subroutine body. In fact, all of the variables you've seen so far are global; that is, they are accessible from every part of your program. This horrifies linguistic purists, but the Perl development team formed an angry mob with torches and ran them out of town years ago. You'll see how to make private variables in the section “**Private Variables in Subroutines**”.

Invoking a Subroutine

You invoke a subroutine from within an expression by using the subroutine name (with the ampersand):

```
&marine; # says Hello, sailor number 1!
&marine; # says Hello, sailor number 2!
&marine; # says Hello, sailor number 3!
&marine; # says Hello, sailor number 4!
```

Most often, you refer to the invocation as simply *calling* the subroutine. You'll also see other ways that you may call the subroutine as you read through this chapter.

Return Values

You always invoke a subroutine as part of an expression, even if you don't use the result of the expression. When you invoked `&marine` earlier, you were calculating the value of the expression containing the invocation but then throwing away the result.

Many times, you call a subroutine and actually do something with the result. This means that you do something with the *return value* of the subroutine. All Perl subroutines have a return value—there's no distinction between those that return values and those that don't. Not all Perl subroutines have a *useful* return value, however.

Since you can call Perl subroutines in a way that needs a return value, it'd be a bit wasteful to have to declare special syntax to “return” a particular value for the majority of the cases. So Larry made it simple. As Perl chugs along in a subroutine, it calculates values as part of its series of actions. Whatever calculation is *last* performed in a subroutine is *automatically* also the return value.

For example, this subroutine has an addition as the last expression:

```
sub sum_of_fred_and_barney {  
    print "Hey, you called the sum_of_fred_and_barney  
subroutine!\n";  
    $fred + $barney;    # That's the return value  
}
```

The last evaluated expression in the body of this subroutine is the sum of `$fred` and `$barney`, so the sum of `$fred` and `$barney` is the return value. Here's that in action:

```
$fred    = 3;  
$barney  = 4;  
$wilma   = &sum_of_fred_and_barney;           # $wilma gets 7  
print "\$wilma is $wilma.\n";  
  
$betty   = 3 * &sum_of_fred_and_barney;       # $betty gets 21  
print "\$betty is $betty.\n";
```

That code produces this output:

```
Hey, you called the sum_of_fred_and_barney subroutine!  
$wilma is 7.  
Hey, you called the sum_of_fred_and_barney subroutine!  
$betty is 21.
```

That `print` statement is just a debugging aid, so you can see that you called the subroutine. You normally take out those sorts of statements when you're ready to deploy your program. But suppose you added another `print` to the end of the subroutine, like this:

```
sub sum_of_fred_and_barney {  
    print "Hey, you called the sum_of_fred_and_barney  
subroutine!\n";  
    $fred + $barney; # That's not really the return value!  
    print "Hey, I'm returning a value now!\n";          # Oops!  
}
```

The last expression evaluated is not the addition anymore; it's now the `print` statement, whose return value is normally 1, meaning “printing was successful,” but that's not the return value you actually wanted. So be careful when adding additional code to a subroutine, since the last expression *evaluated* will be the return value.

NOTE

The return value of `print` is true for a successful operation and false for a failure. You'll see how to determine the kind of failure in [Chapter 5](#).

So, what happened to the sum of `$fred` and `$barney` in that second (faulty) subroutine? You didn't put it anywhere, so Perl discarded it. If you had requested warnings, Perl (noticing that there's nothing useful about adding two variables and discarding the result) would likely warn you about something like “a useless use of addition in a void context.” The term *void context* is just a fancy way of saying that you aren't using the answer, whether that means storing it in a variable or using it any other way.

“The last evaluated expression” really means the last expression that Perl evaluates rather than the last statement in the subroutine. For example, this subroutine returns the larger value of `$fred` or `$barney`:

```
sub larger_of_fred_or_barney {  
    if ($fred > $barney) {  
        $fred;  
    } else {  
        $barney;  
    }  
}
```

The last evaluated expression is either `$fred` or `$barney`, so the value of one of those variables becomes the return value. You don’t know if the return value will be `$fred` or `$barney` until you see what those variables hold at runtime.

These are all rather trivial examples. It gets better when you can pass values that are different for each invocation into a subroutine instead of relying on global variables. In fact, that’s coming right up.

Arguments

That subroutine called `larger_of_fred_or_barney` would be much more useful if it didn’t force you to use the global variables `$fred` and `$barney`. If you wanted to get the larger value from `$wilma` and `$betty`, you currently have to copy those into `$fred` and `$barney` before you can use `larger_of_fred_or_barney`. And if you had something useful in those variables, you’d have to first copy those to other variables—say, `$save_fred` and `$save_barney`. And then, when you’re done with the subroutine, you’d have to copy those back to `$fred` and `$barney` again.

Luckily, Perl has subroutine *arguments*. To pass an argument list to the subroutine, simply place the list expression, in parentheses, after the subroutine invocation, like this:

```
$n = &max(10, 15); # This sub call has two parameters
```

Perl *passes* the list to the subroutine; that is, Perl makes the list available for the subroutine to use however it needs to. Of course, you have to store this list somewhere, so Perl automatically stores the parameter list (another name for the argument list) in the special array variable named `@_` for the duration of the subroutine. You can access this array to determine both the number of arguments and the value of those arguments.

This means that the first subroutine parameter is in `$_[0]`, the second one is stored in `$_[1]`, and so on. But—and here’s an important note—these variables have nothing whatsoever to do with the `$_` variable, any more than `$dino[3]` (an element of the `@dino` array) has to do with `$dino` (a completely distinct scalar variable). It’s just that the parameter list must be in some array variable for your subroutine to use it, and Perl uses the array `@_` for this purpose.

Now, you *could* write the subroutine `&max` to look a little like the subroutine `&larger_of_fred_or_barney`, but instead of using `$fred`, you *could* use the first subroutine parameter (`$_[0]`), and instead of using `$barney`, you *could* use the second subroutine parameter (`$_[1]`). And so you *could* end up with something like this:

```
sub max {
    # Compare this to &larger_of_fred_or_barney
    if ($_[0] > $_[1]) {
        $_[0];
    } else {
        $_[1];
    }
}
```

Well, as we said, you *could* do that. But it’s pretty ugly with all of those subscripts, and it’s hard to read, write, check, and debug too. You’ll see a better way in a moment.

There’s another problem with this subroutine. The name `&max` is nice and short, but it doesn’t remind us that this subroutine works properly only if

called with exactly two parameters:

```
$n = &max(10, 15, 27); # Oops!
```

`max` ignores the extra parameters since it never looks at `$_[2]`. Perl doesn't care whether there's something in there or not. Perl doesn't care about insufficient parameters either—you simply get `undef` if you look beyond the end of the `@_` array, as with any other array. You'll see how to make a better `&max`, which works with any number of parameters, later in this chapter.

The `@_` variable is private to the subroutine; if there's a global value in `@_`, Perl saves it before it invokes the next subroutine and restores its previous value upon return from that subroutine. This also means that a subroutine can pass arguments to another subroutine without fear of losing its own `@_` variable—the nested subroutine invocation gets its own `@_` in the same way. Even if the subroutine calls itself recursively, each invocation gets a new `@_`, so `@_` is always the parameter list for the *current* subroutine invocation.

NOTE

You might recognize that this is the same mechanism as used with the control variable of the `foreach` loop, as seen in [Chapter 3](#). In either case, the variable's value is saved and automatically restored by Perl.

Private Variables in Subroutines

But if Perl can give you a new `@_` for every invocation, can't it give you variables for your own use as well? Of course it can.

By default, all variables in Perl are global variables; that is, they are accessible from every part of the program. But you can create private variables called *lexical variables* at any time with the `my` operator:

```

sub max {
    my($m, $n);      # new, private variables for this block
    ($m, $n) = @_;    # give names to the parameters
    if ($m > $n) { $m } else { $n }
}

```

These variables are private (or *scoped*) to the enclosing block; any other `$m` or `$n` is totally unaffected by these two. And that goes the other way too—no other code can access or modify these private variables, by accident or design. So you could drop this subroutine into any Perl program in the world and know that you wouldn't mess up that program's `$m` and `$n` (if any). Of course, if that program already had a subroutine called `&max`, you'd mess *that* up.

It's also worth pointing out that, inside those `if` blocks, you don't need a semicolon after the return value expression. The semicolon is really a statement separator, not a statement terminator. Although Perl allows you to omit the last semicolon in a block, in practice you omit it only when the code is so simple that you can write the block in a single line.

You can make the subroutine in the previous example even simpler. Did you notice that the list `($m, $n)` shows up twice? You can apply the `my` operator to a list of variables enclosed in parentheses that you use in a list assignment, so it's customary to combine those first two statements in the subroutine:

```

my($m, $n) = @_;    # Name the subroutine parameters

```

That one statement creates the private variables and sets their values, so the first parameter now has the easier-to-use name `$m` and the second has `$n`. Nearly every subroutine starts with a line much like that one, naming its parameters. When you see that line, you'll know that the subroutine expects two scalar parameters, which you'll call `$m` and `$n` inside the subroutine.

Variable-Length Parameter Lists

In real-world Perl code, subroutines often have parameter lists of arbitrary length. That's because of Perl's “no unnecessary limits” philosophy that you've already seen. Of course, this is unlike many traditional programming languages, which require every subroutine to be strictly typed; that is, to permit only a certain predefined number of parameters of predefined types. It's nice that Perl is so flexible, but (as you saw with the `&max` routine earlier) that may cause problems when you call a subroutine with a different number of arguments than it expects.

Of course, you can easily check that the subroutine has the right number of arguments by examining the `@_` array. For example, you could have written `&max` to check its argument list like this:

```
sub max {
    if (@_ != 2) {
        print "WARNING! &max should get exactly two arguments!\n";
    }
    # continue as before...
}
```

That `if` test uses the “name” of the array in a scalar context to find out the number of array elements, as you saw in [Chapter 3](#).

But in real-world Perl programming, virtually no one really uses this sort of check; it's better to make your subroutines adapt to the parameters.

A Better `&max` Routine

Rewrite `&max` to allow for any number of arguments, so you can call it like this:

```
$maximum = &max(3, 5, 10, 4, 6);

sub max {
    my($max_so_far) = shift @_; # the first one is the largest yet
    seen
    foreach (@_) {              # look at the remaining arguments
        if ($_ > $max_so_far) {  # could this one be bigger yet?
            $max_so_far = $_;
        }
    }
}
```

```
}  
$max_so_far;  
}
```

This code uses what has often been called the *high-water mark* algorithm; after a flood, when the waters have surged and receded for the last time, the high-water mark shows where the highest water was seen. In this routine, `$max_so_far` keeps track of our high-water mark, the largest number yet seen, in the `$max_so_far` variable.

The first line sets `$max_so_far` to 3 (the first parameter in the example code) by shifting that parameter from the parameter array, `@_`. So `@_` now holds (5, 10, 4, 6), since you removed the 3. And the largest number yet seen is the *only* one yet seen: 3, the first parameter.

Next, the `foreach` loop steps through the remaining values in the parameter list, from `@_`. The control variable of the loop is, by default, `$_`. (But remember, there's no automatic connection between `@_` and `$_`; it's just a coincidence that they have such similar names.) The first time through the loop, `$_` is 5. The `if` test sees that it is larger than `$max_so_far`, so it sets `$max_so_far` to 5—the new high-water mark.

The next time through the loop, `$_` is 10. That's a new record high, so you store it in `$max_so_far` as well.

The next time, `$_` is 4. The `if` test fails, since that's not larger than `$max_so_far`, which is 10, so you skip the body of the `if`.

Finally, `$_` is 6, and you skip the body of the `if` again. And that was the last time through the loop, so the loop is done.

Now, `$max_so_far` becomes the return value. It's the largest number you've seen, and you've seen them all, so it must be the largest from the list: 10.

Empty Parameter Lists

That improved `&max` algorithm works fine now, even if there are more than two parameters. But what happens if there are none?

At first, it may seem too esoteric to worry about. After all, why would someone call `&max` without giving it any parameters? But maybe someone wrote a line like this one:

```
$maximum = &max(@numbers);
```

And the array `@numbers` might sometimes be an empty list; perhaps it was read in from a file that turned out to be empty, for example. So you need to know: what does `&max` do in that case?

The first line of the subroutine sets `$max_so_far` by using `shift` on `@_`, the (now empty) parameter array. That's harmless; the array is left empty, and `shift` returns `undef` to `$max_so_far`.

Now the `foreach` loop wants to iterate over `@_`, but since that's empty, you execute the loop body zero times.

So in short order, Perl returns the value of `$max_so_far`—`undef`—as the return value of the subroutine. In some sense, that's the right answer because there is no largest (non)value in an empty list.

Of course, whoever called this subroutine should be aware that the return value may be `undef`—or they could simply ensure that the parameter list is never empty.

Notes on Lexical (my) Variables

Those lexical variables can actually be used in any block, not merely in a subroutine's block. For example, they can be used in the block of an `if`, `while`, or `foreach`:

```
foreach (1..10) {  
    my($square) = $_ * $_; # private variable in this loop  
    print "$_ squared is $square.\n";  
}
```

The variable `$square` is private to the enclosing block; in this case, that's the block of the `foreach` loop. If there's no enclosing block, the variable is private to the entire source file.

For now, your programs aren't going to use more than one source file, so this isn't an issue. But the important concept is that the `scope` of a lexical variable's name is limited to the smallest enclosing block or file. The *only* code that can say `$square` and mean that variable is the code inside that textual scope.

This is a big win for maintainability—if you find a wrong value in `$square`, you should also find the culprit within a limited amount of source code. As experienced programmers have learned (often the hard way), limiting the scope of a variable to a page of code, or even to a few lines of code, really speeds along the development and testing cycle.

A file is a scope too, so a lexical variable in one file isn't visible in another. However, we put off covering reusable libraries and modules until

Intermediate Perl.

Note also that the `my` operator doesn't change the context of an assignment:

```
my($num) = @_; # list context, same as ($num) = @_;  
my $num = @_; # scalar context, same as $num = @_;
```

In the first one, `$num` gets the first parameter, as a list-context assignment; in the second, it gets the number of parameters, in a scalar context. Either line of code *could* be what the programmer wanted; you can't tell from that one line alone, and so Perl can't warn you if you use the wrong one. (Of course, you wouldn't have *both* of those lines in the same subroutine, since you can't have two lexical variables with the same name declared in the same scope; this is just an example.) So, when reading code like this, you can always tell the context of the assignment by seeing what the context would be without the word `my`.

Remember that without the parentheses, `my` only declares a *single* lexical variable:

```
my $fred, $barney;      # WRONG! Fails to declare $barney
my($fred, $barney);     # declares both
```

Of course, you can use `my` to create new, private arrays as well:

```
my @phone_number;
```

Any new variable will start out empty—`undef` for scalars, or the empty list for arrays.

In regular Perl programming, you'll probably use `my` to introduce any new variable in a scope. In [Chapter 3](#), you saw that you could define your own control variable with the `foreach` structure. You can make that a lexical variable too:

```
foreach my $rock (qw/ bedrock slate lava /) {
    print "One rock is $rock.\n"; # Prints names of three rocks
}
```

This is important in the next section, where you start using a feature that makes you declare all your variables.

The use strict Pragma

Perl tends to be a pretty permissive language. But maybe you want Perl to impose a little discipline; that can be arranged with the `use strict` pragma.

A *pragma* is a hint to a compiler, telling it something about the code. In this case, the `use strict` pragma tells Perl's internal compiler that it should enforce some good programming rules for the rest of this block or source file.

Why would this be important? Well, imagine that you're composing your program and you type a line like this one:

```
$bamm_bamm = 3; # Perl creates that variable automatically
```

Now, you keep typing for a while. After that line has scrolled off the top of the screen, you type this line to increment the variable:

```
$bammbamm += 1;  # Oops!
```

Since Perl sees a new variable name (the underscore *is* significant in a variable name), it creates a new variable and increments that one. If you're lucky and smart, you've turned on warnings, and Perl can tell you that you used one or both of those global variable names only a single time in your program. But if you're merely smart, you used each name more than once, and Perl won't be able to warn you.

To tell Perl that you're ready to be more restrictive, put the `use strict` pragma at the top of your program (or in any block or file where you want to enforce these rules):

```
use strict;  # Enforce some good programming rules
```

Starting with Perl 5.12, you implicitly use this pragma when you declare a minimum Perl version:

```
use v5.12; # loads strict for you
```

Now, among other restrictions, Perl will insist that you declare every new variable, usually done with `my`:

```
my $bamm_bamm = 3;  # New lexical variable
```

Now if you try to spell it the other way, Perl recognizes the problems and complains that you haven't declared any variable called `$bammbamm`, so your mistake is automatically caught at compile time:

```
$bammbamm += 1;  # No such variable: Compile time fatal error
```

Of course, this applies only to new variables; you don't need to declare Perl's built-in variables, such as `$_` and `@_`. If you add `use strict` to an

already written program, you'll generally get a flood of warning messages, so it's better to use it from the start, when it's needed.

NOTE

`use strict` doesn't check variables named `$a` and `$b` because `sort` uses those global variables. They aren't very good variable names anyway.

Most people recommend that programs that are longer than a screenful of text generally need `use strict`. And we agree.

From here on, we'll write most (but not all) of our examples as if `use strict` is in effect even where we don't show it. That is, we'll generally declare variables with `my` where it's appropriate. Although we don't always do so here, we encourage you to include `use strict` in your programs as often as possible. You'll thank us in the long run.

The return Operator

What if you want to stop your subroutine right away? The `return` operator immediately returns a value from a subroutine:

```
my @names = qw/ fred barney betty dino wilma pebbles bamm-bamm /;
my $result = &which_element_is("dino", @names);

sub which_element_is {
    my($what, @array) = @_;
    foreach (0..$#array) { # indices of @array's elements
        if ($what eq $array[$_]) {
            return $_;      # return early once found
        }
    }
    -1;                    # element not found (return is optional
here)
}
```

You're asking this subroutine to find the index of `dino` in the array `@names`. First, the `my` declaration names the parameters: there's `$what`, which is what you're searching for, and `@array`, an array of values to search within. That's a copy of the array `@names`, in this case. The `foreach` loop steps through the indices of `@array` (the first index is 0, and the last one is `$#array`, as you saw in [Chapter 3](#)).

Each time through the `foreach` loop, you check to see whether the string in `$what` is equal to the element from `@array` at the current index. If it's equal, you return that index at once. This is the most common use of the keyword `return` in Perl—to return a value immediately, without executing the rest of the subroutine.

But what if you never found that element? In that case, the author of this subroutine has chosen to return `-1` as a “value not found” code. It would be more Perl-ish, perhaps, to return `undef` in that case, but this programmer used `-1`. Saying `return -1` on that last line would be correct, but the word `return` isn't really needed.

Some programmers like to use `return` every time there's a return value, as a means of documenting that it *is* a return value. For example, you might use `return` when the return value is not the last line of the subroutine, such as in the subroutine `&larger_of_fred_or_barney`, earlier in this chapter. You don't really need it, but it doesn't hurt anything either. However, many Perl programmers believe it's just an extra seven characters of typing.

Omitting the Ampersand

As promised, now we'll tell you the rule for when you can omit the ampersand on a subroutine call. If the compiler sees the subroutine definition before invocation, or if Perl can tell from the syntax that it's a subroutine call, the subroutine can be called without an ampersand, just like a built-in function. (But there's a catch hidden in that rule, as you'll see in a moment.)

This means that if Perl can see that it's a subroutine call without the ampersand, from the syntax alone, that's generally fine. That is, if you've got the parameter list in parentheses, it's got to be a function call:

```
my @cards = shuffle(@deck_of_cards); # No & necessary on
&shuffle
```

In this case, the function is the subroutine `&shuffle`. But it may be a built-in function, as you'll see in a moment.

Or, if Perl's internal compiler has already seen the subroutine definition, that's generally OK too. In that case, you can even omit the parentheses around the argument list:

```
sub division {
    $_[0] / $_[1];                # Divide first param by second
}

my $quotient = division 355, 113; # Uses &division
```

This works because of the rule that you may always omit parentheses when they don't change the meaning of the code. You can't omit those parentheses if you use the `&`, though.

However, don't put that subroutine declaration after the invocation; if you do, the compiler won't know what the attempted invocation of `division` is all about. The compiler has to see the definition before the invocation in order to use the subroutine call as if it were a built-in. Otherwise, the compiler doesn't know what to do with that expression because it doesn't know what `division` is yet.

NOTE

As with many things in this book, our use of the `&` is expedient for teaching you the Perl language rather than teaching you to be an experienced Perl programmer. Some people disagree. We say more about this in the [“Why we teach the subroutine ampersand”](#) blog post.

That's not the catch, though. The catch is this: if the subroutine has the same name as a Perl built-in, you *must* use the ampersand to call your version. With an ampersand, you're sure to call the subroutine; without it, you can get the subroutine *only* if there's no built-in with the same name:

```
sub chomp {  
    print "Munch, munch!\n";  
}  
  
&chomp; # That ampersand is not optional!
```

Without the ampersand, you'd be calling the built-in `chomp`, even though you've defined the subroutine `&chomp`. So the real rule to use is this one: until you know the names of all of Perl's built-in functions, use the ampersand on function calls. That means you will use it for your first one hundred or so programs. But when you see someone else has omitted the ampersand in their own code, it's not a mistake; perhaps they simply know that Perl has no built-in with that name.

Nonscalar Return Values

A scalar isn't the only kind of return value a subroutine may have. If you call your subroutine in a list context, it can return a list of values.

NOTE

You can detect whether a subroutine is being evaluated in a scalar or list context using the `wantarray` function, which lets you easily write subroutines with specific list or scalar context values.

Suppose you want to get a range of numbers (as from the range operator, `..`), except that you want to be able to count down as well as up. The range operator only counts upward, but that's easily fixed:

```

sub list_from_fred_to_barney {
    if ($fred < $barney) {
        # Count upward from $fred to $barney
        $fred..$barney;
    } else {
        # Count downward from $fred to $barney
        reverse $barney..$fred;
    }
}

$fred = 11;
$barney = 6;
@c = &list_from_fred_to_barney; # @c gets (11, 10, 9, 8, 7, 6)

```

In this case, the range operator gives you the list from 6 to 11, then `reverse` reverses the list so that it goes from `$fred` (11) to `$barney` (6), just as we wanted.

The least you can return is nothing at all. A `return` with no arguments will return `undef` in a scalar context or an empty list in a list context. This can be useful for an error return from a subroutine, signaling to the caller that a more meaningful return value is unavailable.

Persistent, Private Variables

With `my`, you were able to make variables private to a subroutine, although each time you called the subroutine you had to define them again. With `state`, you can still have private variables scoped to the subroutine, but Perl will keep their values between calls.

Going back to the first example in this chapter, you had a subroutine named `marine` that incremented a variable:

```

sub marine {
    $n += 1; # Global variable $n
    print "Hello, sailor number $n!\n";
}

```

Now that you know about `strict`, you add that to your program and realize that your use of the global variable `$n` is now a compilation error. You can't make `$n` a lexical variable with `my` because it wouldn't retain its value between calls.

Declaring our variable with `state` tells Perl to retain the variable's value between calls to the subroutine and to make the variable private to the subroutine. This feature showed up in Perl 5.10:

```
use v5.10;

sub marine {
    state $n = 0; # private, persistent variable $n
    $n += 1;
    print "Hello, sailor number $n!\n";
}
```

Now you can get the same output while being `strict`-clean and not using a global variable. The first time you call the subroutine, Perl declares and initializes `$n`. Perl ignores the statement on all subsequent calls. Between calls, Perl retains the value of `$n` for the next call to the subroutine.

You can make any variable type a `state` variable; it's not just for scalars. Here's a subroutine that remembers its arguments and provides a running sum by using a `state` array:

```
use v5.10;

running_sum( 5, 6 );
running_sum( 1..3 );
running_sum( 4 );

sub running_sum {
    state $sum = 0;
    state @numbers;

    foreach my $number ( @_ ) {
        push @numbers, $number;
        $sum += $number;
    }
}
```

```
    say "The sum of (@numbers) is $sum";
}
```

This outputs a new sum each time you call it, adding the new arguments to all of the previous ones:

```
The sum of (5 6) is 11
The sum of (5 6 1 2 3) is 17
The sum of (5 6 1 2 3 4) is 21
```

There's a slight restriction on arrays and hashes as `state` variables, though. You can't initialize them in list contexts as of Perl 5.10:

```
state @array = qw(a b c); # Error!
```

This gives you an error that hints that you might be able to do it in a future version of Perl, but as of Perl 5.24, you still can't:

```
Initialization of state variables in list context currently
forbidden ...
```

This restriction is lifted in Perl 5.28, which allows you to initialize arrays and hashes in `state`. For example, a Fibonacci number generator needs the first two numbers to get started, so you seed the `@numbers` array with them:

```
use v5.28;

say next_fibonacci(); # 1
say next_fibonacci(); # 2
say next_fibonacci(); # 3
say next_fibonacci(); # 5

sub next_fibonacci {
    state @numbers = ( 0, 1 );
    push @numbers, $numbers[-2] + $numbers[-1];
    return $numbers[-1];
}
```

Prior to v5.28, you could have used an array reference instead since all references are scalars. However, we don't tell you about those until *Intermediate Perl*.

Subroutine Signatures

Perl v5.20 added a long-awaited and exciting feature called *subroutine signatures*. So far it's experimental (see [Appendix D](#)), but we're hoping it's stable soon. We think it deserves a section in this chapter, even if to merely tease you with it.

Subroutine signatures are different from prototypes, a much different feature that many people have tried to use for the same reason. If you don't know what a prototype is, that's good. You probably don't need to know about them, at least not in this book.

So far, you have seen subroutines that take a list of arguments in `@_` and then assign them to variables. You saw that earlier in the `max` subroutine:

```
sub max {  
    my ($m, $n);  
    ($m, $n) = @_  
    if ($m > $n) { $m } else { $n }  
}
```

First, you have to enable this experimental feature (see [Appendix D](#)):

```
use v5.20;  
use experimental qw(signatures);
```

After that, we can move the variable declarations outside the braces right after the subroutine names:

```
sub max ( $m, $n ) {  
    if ($m > $n) { $m } else { $n }  
}
```


That's an exceedingly pleasant syntax. The variables are still private to the subroutine, but you type much less to declare and assign to them. Perl handles that for you. Otherwise, the subroutine is the same.

Well, it's almost the same. Previously, you could pass any number of arguments to `&max` even if you only used the first two of them. That doesn't work anymore:

```
&max( 137, 48, 7 );
```

You get an error if you try this:

```
Too many arguments for subroutine
```

The signature feature is also checking the number of arguments for you! But you want to take the maximum of a list of numbers where you don't know the length of the list. You can modify the subroutine in the same way you modified it earlier. You can use an array in the signature:

```
sub max ( $max_so_far, @rest ) {
    foreach (@rest) {
        if ($_ > $max_so_far) {
            $max_so_far = $_;
        }
    }
    $max_so_far;
}
```

You don't have to define an array to slurp up the rest of the arguments, though. If you use a plain `@`, Perl knows the subroutine can take a variable number of arguments. The argument list still shows up in `@_`:

```
sub max ( $max_so_far, @ ) {
    foreach (@_) {
        if ($_ > $max_so_far) {
            $max_so_far = $_;
        }
    }
    $max_so_far;
}
```

That handles the case of too many arguments, but what about too few arguments? Signatures can also specify defaults:

```
sub list_from_fred_to_barney ( $fred = 0, $barney = 7 ) {  
    if ($fred < $barney) { $fred..$barney }  
    else { reverse $barney..$fred }  
}
```

```
my @defaults      = list_from_fred_to_barney();  
my @default_end   = list_from_fred_to_barney( 17 );  
  
say "defaults: @defaults";  
say "default_end: @default_end";
```

When you run this, you can see the default values at work:

```
defaults: 0 1 2 3 4 5 6 7  
default_end: 17 16 15 14 13 12 11 10 9 8 7
```

Sometimes you want optional arguments that don't have defaults. You can use the `$=` placeholder to denote an optional argument:

```
sub one_or_two_args ( $first, $= ) { ... }
```

There's a Perl special variable for formats, `$=`, but that's not what's going on here.

And sometimes you want exactly zero arguments. You could create a constant value like this:

```
sub PI () { 3.1415926 }
```

You can read more about signatures in [perlsub](#). We also write about them in the [“Use v5.20 subroutine signatures”](#) blog post.

Prototypes

Prototypes are an older Perl feature that allows you to tell the parser how to interpret your source; they are a primitive form of signatures that never evolved. It's not a feature that we recommend, but it does clash with signatures, so we want to mention them merely so you know they exist.

Suppose you want a subroutine that takes exactly two arguments. You could note that in the prototype. Since those are instructions to the parser, you need the prototype to show up before any call to the subroutine:

```
sub sum ($$) { $_[0] + $_[1] }

print sum( 1, 3, 7 );
```

This code gives you a compilation error because `sum` has one more argument than it should:

```
Too many arguments for main::sum
```

Prototypes and signatures both use parentheses after the name in a subroutine definition, and each has its own syntax. That's a problem if you want to use both. To get around this, v5.20 also adds the `:prototype` attribute, another feature we aren't going to explain other than to note how you preserve prototypes while also using signatures. Put `:prototype` before the parentheses:

```
sub sum :prototype($$) { $_[0] + $_[1] }

print sum( 1, 3, 7 );
```

We advise that you avoid prototypes altogether unless you understand what you are doing. Even then, you may want to think twice about it. The full details are in [perlsyn](#). If you have no idea what we're talking about, that's fine, because you won't see this again in this book!

Exercises

See “[Answers to Chapter 4 Exercises](#)” for answers to these exercises:

1. [12] Write a subroutine, named `total`, that returns the total of a list of numbers. Hint: the subroutine should *not* perform any I/O; it should simply process its parameters and return a value to its caller. Try it out in this sample program, which merely exercises the subroutine to see that it works. The first group of numbers should add up to 25.

```
my @fred = qw{ 1 3 5 7 9 };
my $fred_total = total(@fred);
print "The total of \@fred is $fred_total.\n";
print "Enter some numbers on separate lines: ";
my $user_total = total(<STDIN>);
print "The total of those numbers is $user_total.\n";
```

Note that using `<STDIN>` in list context like that will wait for you to end input in whatever way is appropriate for your system.

2. [5] Using the subroutine from the previous problem, make a program to calculate the sum of the numbers from 1 to 1,000.
3. [18] Extra credit exercise: write a subroutine, called `&above_average`, that takes a list of numbers and returns the ones above the average (mean). (Hint: make another subroutine that calculates the average by dividing the total by the number of items.) Try your subroutine in this test program:

```
my @fred = above_average(1..10);
print "\@fred is @fred\n";
print "(Should be 6 7 8 9 10)\n";
my @barney = above_average(100, 1..10);
print "\@barney is @barney\n";
print "(Should be just 100)\n";
```

4. [10] Write a subroutine named `greet` that welcomes the person you name by telling them the name of the last person it greeted:

```
greet( "Fred" );  
greet( "Barney" );
```

This sequence of statements should print:

```
Hi Fred! You are the first one here!  
Hi Barney! Fred is also here!
```

5. [10] Modify the previous program to tell each new person the names of all the people it has previously greeted:

```
greet( "Fred" );  
greet( "Barney" );  
greet( "Wilma" );  
greet( "Betty" );
```

This sequence of statements should print:

```
Hi Fred! You are the first one here!  
Hi Barney! I've seen: Fred  
Hi Wilma! I've seen: Fred Barney  
Hi Betty! I've seen: Fred Barney Wilma
```

Chapter 5. Input and Output

You’ve already seen how to do some input/output (I/O) in order to make some of the earlier exercises possible. But now you’ll learn more about those operations by covering the 80% of the I/O you’ll need for most programs. If you’re already familiar with the workings of standard input, output, and error streams, you’re ahead of the game. If not, we’ll get you caught up by the end of this chapter. For now, just think of “standard input” as being “the keyboard,” and “standard output” as being “the display screen.”

Input from Standard Input

Reading from the standard input stream is easy. You’ve been doing it already with the `<STDIN>` operator. Evaluating this operator in a scalar context gives you the next line of input:

```
$line = <STDIN>;           # read the next line
chomp($line);              # and chomp it

chomp($line = <STDIN>);     # same thing, more idiomatically
```

What we’re calling the line-input operator here, `<STDIN>`, is actually a line-input operator (represented by the angle brackets) around a *filehandle*. You’ll learn about filehandles later in this chapter.

Since the line-input operator will return `undef` when you reach end-of-file, this is handy for dropping out of loops:

```
while (defined($line = <STDIN>)) {
    print "I saw $line";
}
```

There's a lot going on in that first line: you're reading the input into a variable, checking that it's defined, and if it is (meaning that we haven't reached the end of the input), you're running the body of the `while` loop. So, inside the body of the loop, you'll see each line, one after another, in `$line`. This is something you'll want to do fairly often, so naturally Perl has a shortcut for it. The shortcut looks like this:

```
while (<STDIN>) {  
    print "I saw $_";  
}
```

Now, to make this shortcut, Larry chose some useless syntax. That is, this is *literally* saying, “Read a line of input, and see if it's true. (Normally it is.) And if it is true, enter the `while` loop, but *throw away that line of input!*” Larry knew that it was a useless thing to do; nobody should ever need to do that in a real Perl program. So Larry took this useless syntax and made it useful.

What this is *actually* saying is that Perl should do the same thing as you saw in our earlier loop: it tells Perl to read the input into a variable, and (as long as the result was defined, so you haven't reached end-of-file) then enter the `while` loop. However, instead of storing the input in `$line`, Perl uses its favorite default variable, `$_`, just as if you had written this:

```
while (defined($_ = <STDIN>)) {  
    print "I saw $_";  
}
```

Now, before you go any further, we must be very clear about something: this shortcut works *only* if you write it just like that. If you put a line-input operator anywhere else (in particular, as a statement all on its own), it won't read a line into `$_` by default. It works *only* if there's nothing but the line-input operator in the conditional of a `while` loop. If you put anything else into the conditional expression, this shortcut won't apply.

There's otherwise no other connection between the line-input operator (`<STDIN>`) and Perl's favorite default variable (`$_`). In this case, though, it

just happens that Perl is storing the input in that variable.

On the other hand, evaluating the line-input operator in a list context gives you all of the (remaining) lines of input as a list—each element of the list is one line:

```
foreach (<STDIN>) {  
    print "I saw $_";  
}
```

Once again, there's no connection between the line-input operator and Perl's favorite default variable. In this case, though, the default control variable for `foreach` is `$_`. So in this loop, you see each line of input in `$_`, one after the other.

That may sound familiar, and for good reason: that's the same thing the `while` loop would do. Isn't it?

The difference is under the hood. In the `while` loop, Perl reads a single line of input, puts it into a variable, and runs the body of the loop. Then it goes back to find another line of input. But in the `foreach` loop, you're using the line-input operator in a list context (since `foreach` needs a list to iterate through); you read all of the input before the loop can start running. That difference will become apparent when the input is coming from your 400 MB web server logfile! It's generally best to use code like the `while` loop's shortcut, which will process input a line at a time, whenever possible.

Input from the Diamond Operator

Another way to read input is with the diamond operator: `<>`. This is useful for making programs that work like standard Unix utilities, with respect to the invocation arguments (which we'll see in a moment). If you want to make a Perl program that can be used like the utilities *cat*, *sed*, *awk*, *sort*, *grep*, *lpr*, and many others, the diamond operator will be your friend. If you want to make anything else, the diamond operator probably won't help.

NOTE

Randal went over to Larry's house one day to show off the new training materials he'd been writing and complained that there was no spoken name for "that thing." Larry didn't have a name for it either. Heidi (eight years old at the time) quickly chimed in, "That's a diamond, Daddy." So the name stuck. Thanks, Heidi!

The *invocation arguments* to a program are normally a number of "words" on the command line after the name of the program. In this case, they give the names of the files your program will process in sequence:

```
$ ./my_program fred barney betty
```

That command means to run the command *my_program* (which will be found in the current directory), and that it should process file *fred*, followed by file *barney*, followed by file *betty*.

If you give no invocation arguments, the program should process the standard input stream. Or, as a special case, if you give just a hyphen as one of the arguments, that means standard input as well. So, if the invocation arguments had been *fred - betty*, that would have meant that the program should process file *fred*, followed by the standard input stream, followed by file *betty*.

The benefit of making your programs work like this is that you may choose where the program gets its input at runtime; for example, you won't have to rewrite the program to use it in a pipeline (which we'll show more later). Larry put this feature into Perl because he wanted to make it easy for you to write your own programs that work like standard Unix utilities—even on non-Unix machines. Actually, he did it so he could make his *own* programs work like standard Unix utilities; since some vendors' utilities don't work just like others', Larry could make his own utilities, deploy them on a number of machines, and know that they'd all have the same behavior. Of course, this meant porting Perl to every machine he could find.

The diamond operator is actually a special kind of line-input operator. But instead of getting the input from the keyboard, it comes from the user's choice of input:

```
while (defined($line = <>)) {  
    chomp($line);  
    print "It was $line that I saw!\n";  
}
```

So, if you run this program with the invocation arguments *fred*, *barney*, and *betty*, it will say something like: “It was [a line from file *fred*] that I saw!”, “It was [another line from file *fred*] that I saw!”, on and on until it reaches the end of file *fred*. Then it will automatically go on to file *barney*, printing out one line after another, and then on through file *betty*. Note that there's no break when you go from one file to another; when you use the diamond, it's as if the input files have been merged into one big file. The diamond will return `undef` (and we'll drop out of the `while` loop) only at the end of all of the input.

NOTE

If it matters to you, or even if it doesn't, the current file's name is kept in Perl's special variable `$ARGV`. This name may be `"-"` instead of a real filename if the input is coming from the standard input stream, though.

In fact, since this is just a special kind of line-input operator, you may use the same shortcut you saw earlier to read the input into `$_` by default:

```
while (<>) {  
    chomp;  
    print "It was $_ that I saw!\n";  
}
```

This works like the loop from before but with less typing. And you may have noticed that you use the default for `chomp`; without an argument, `chomp` works on `$_`. Every little bit of saved typing helps!

Since you generally use the diamond operator to process all of the input, it's typically a mistake to use it in more than one place in your program. If you find yourself putting two diamonds into the same program, especially using the second diamond inside the `while` loop that is reading from the first one, it's almost certainly not going to do what you would like. In our experience, when beginners put a second diamond into a program, they meant to use `$_` instead. Remember, the diamond operator *reads* the input, but the input itself is (generally, by default) found in `$_`.

If the diamond operator can't open one of the files and read from it, it'll print an allegedly helpful diagnostic message, such as:

```
can't open wilma: No such file or directory
```

The diamond operator will then go on to the next file automatically, much like what you'd expect from *cat* or another standard utility.

The Double Diamond

There's a problem with the diamond operator that has a fix in v5.22. Suppose that the filename from the command line has a special character in it, such as `|`. This might cause *perl* to perform a "pipe open" (see [Chapter 15](#)), which runs an external program and reads that program's output as if it were a file. The "double diamond" operator, `<<>>`, prevents this. It's the same as the diamond operator you just saw but without the magic that will run external programs:

```
use v5.22;

while (<<>>) {
    chomp;
    print "It was $_ that I saw!\n";
}
```

If you have v5.22 or later, you should use this version instead. We might have liked someone to fix the good ol' single diamond operator, but that

might break something that someone has relied on for years. Instead, the Perl developers maintained backward compatibility.

For the rest of this book, we'll say "diamond operator," leaving it up to you to choose which one you want to use. We'll use the old single diamond to drag along the people on older versions.

The Invocation Arguments

Technically, the diamond operator isn't looking literally at the invocation arguments—it works from the `@ARGV` array. This array is a special array that is preset by the Perl interpreter as the list of the invocation arguments. In other words, this is just like any other array (except for its funny, all-caps name), but when your program starts, `@ARGV` is already stuffed full of the list of invocation arguments.

You can use `@ARGV` just like any other array; you could `shift` items off of it, perhaps, or use `foreach` to iterate over it. You could even check to see if any arguments start with a hyphen so that you could process them as invocation options (like Perl does with its own `-w` option).

NOTE

If you need more than just one or two such options, you should almost certainly use a module to process them in a standard way. See the documentation for the `Getopt::Long` and `Getopt::Std` modules, which are part of the standard distribution.

The diamond operator looks in `@ARGV` to determine what filenames it should use. If it finds an empty list, it uses the standard input stream; otherwise, it uses the list of files that it finds. This means that after your program starts and before you start using the diamond, you've got a chance to tinker with `@ARGV`. For example, you can process three specific files, regardless of what the user chose on the command line:

```
@ARGV = qw# larry moe curly #; # force these three files to be
read
while (<>) {
    chomp;
    print "It was $_ that I saw in some stooge-like file!\n";
}
```

Output to Standard Output

The `print` operator takes a list of values and sends each item (as a string, of course) to standard output in turn, one after another. It doesn't add any extra characters before, after, or in between the items; if you want spaces between items and a newline at the end, you have to say so:

```
$name = "Larry Wall";
print "Hello there, $name, did you know that 3+4 is ", 3+4, "?
\n";
```

Of course, that means that there's a difference between printing an array and interpolating an array:

```
print @array;      # print a list of items
print "@array";    # print a string (containing an interpolated
array)
```

That first `print` statement will print a list of items, one after another, with no spaces in between. The second one will print exactly one item, which is the string you get by interpolating `@array` into the empty string—that is, it prints the contents of `@array`, separated by spaces. So, if `@array` holds `qw/ fred barney betty /`, the first one prints `fredbarneybetty`, while the second prints `fred barney betty` separated by spaces. But before you decide to always use the second form, imagine that `@array` is a list of unchomped lines of input. That is, imagine that each of its strings has a trailing newline character. Now, the first `print` statement prints `fred`, `barney`, and `betty` on three separate lines. But the second one prints this:

```
fred
  barney
  betty
```

Do you see where the spaces come from? Perl is interpolating an array, so it puts spaces between the elements (actually, whatever is in the variable `$`). So we get the first element of the array (`fred` and a newline character), then a space, then the next element of the array (`barney` and a newline character), then a space, then the last element of the array (`betty` and a newline character). The result is that the lines seem to have become indented, except for the first one.

Every week or two, we encounter a question like “Perl indents everything after the first line.” Without even reading the message, we can immediately see that the program used double quotes around an array containing unchomped strings. “Did you perhaps put an array of unchomped strings inside double quotes?” we ask, and the answer is always “yes.”

Generally, if your strings contain newlines, you simply want to print them, after all:

```
print @array;
```

But if they don’t contain newlines, you generally want to add one at the end:

```
print "@array\n";
```

So, if you use the quote marks, you’re (generally) adding the `\n` at the end of the string anyway; this should help you remember which is which.

It’s normal for your program’s output to be *buffered*. That is, instead of sending out every little bit of output at once, your program saves the output until there’s enough to bother with.

If, for example, you want to save the output to disk, it’s (relatively) slow and inefficient to spin the disk every time you add one or two characters to the file. Generally, then, the output will go into a buffer that is *flushed* (that

is, actually written to disk, or wherever) only when the buffer gets full, or when the output is otherwise finished (such as at the end of runtime).

Usually, that's what you want.

But if you (or a program) may be waiting impatiently for the output, you may wish to take that performance hit and flush the output buffer each time you `print`. See `$!` in the [perlvar documentation](#) for more information on controlling buffering in that case.

Since `print` is looking for a list of strings to print, it evaluates its arguments in list context. Since the diamond operator (as a special kind of line-input operator) returns a list of lines in a list context, these can work well together:

```
print <>;          # implementation of /bin/cat

print sort <>;     # implementation of /bin/sort
```

Well, to be fair, the standard Unix commands *cat* and *sort* do have some additional functionality that these replacements lack. But you can't beat them for the price! You can now reimplement all of your standard Unix utilities in Perl and painlessly port them to any machine that has Perl, whether that machine is running Unix or not. And you can be sure that the programs on every different type of machine will nevertheless have the same behavior.

NOTE

The [Perl Power Tools project](#), whose goal is to implement all of the classic Unix utilities in Perl, completed nearly all the utilities. Perl Power Tools has been helpful because it has made these standard utilities available on many non-Unix machines.

What might not be obvious is that `print` has optional parentheses, which can sometimes cause confusion. Remember the rule that parentheses in Perl may always be omitted—except when doing so would change the meaning of a statement. So, here are two ways to print the same thing:

```
print("Hello, world!\n");  
print "Hello, world!\n";
```

So far, so good. But another rule in Perl is that if the invocation of `print` *looks* like a function call, then it *is* a function call. It's a simple rule, but what does it mean for something to look like a function call?

In a function call, there's a function name immediately followed by parentheses around the function's arguments, like this:

```
print (2+3);
```

That looks like a function call, so it is a function call. It prints 5, but it returns a value like any other function. The return value of `print` is a true or false value, indicating the success of the print. It nearly always succeeds, unless you get some I/O error, so the `$result` in the following statement will normally be 1:

```
$result = print("hello world!\n");
```

But what if you use the result in some other way? Suppose you decide to multiply the return value by four:

```
print (2+3)*4; # Oops!
```

When Perl sees this line of code, it prints 5, just as you asked. Then it takes the return value from `print`, which is 1, and multiplies that by 4. It then throws away the product, wondering why you didn't tell it to do something else with it. And at this point, someone looking over your shoulder says, "Hey, Perl can't do math! That should have printed 20 rather than 5!"

This is the problem with the optional parentheses; sometimes we humans forget where the parentheses really belong. When there are no parentheses, `print` is a list operator, printing all of the items in the following list; that's generally what you'd expect. But when the first thing after `print` is a left parenthesis, `print` is a function call, and it will print only what's found

inside the parentheses. Since that line had parentheses, it's the same to Perl as if you'd said this:

```
( print(2+3) ) * 4;  # Oops!
```

Fortunately, Perl itself can almost always help you with this, if you ask for warnings—so use `-w`, or use `warnings`, at least during program development and debugging. To fix this, use more parentheses:

```
print( (2+3) * 4 );
```

Actually, this rule—“If it looks like a function call, it is a function call”—applies to all list functions in Perl, not just to `print`. It's just that you're most likely to notice it with `print`. If `print` (or another function name) is followed by an opening parenthesis, make sure that the corresponding closing parenthesis comes after *all* of the arguments to that function.

Formatted Output with `printf`

You may wish to have a little more control with your output than `print` provides. In fact, you may be accustomed to the formatted output of C's `printf` function. Fear not! Perl provides a comparable operation with the same name.

The `printf` operator takes a template string followed by a list of things to print. That string is a fill-in-the-blanks template showing the desired form of the output:

```
printf "Hello, %s; your password expires in %d days!\n",  
      $user, $days_to_die;
```

The template string holds a number of so-called *conversions*; each conversion begins with a percent sign (%) and ends with a letter. (As you'll see in a moment, there may be significant extra characters between these two symbols.) There should be the same number of items in the following

list as there are conversions; if these don't match up, it won't work correctly. In the preceding example, there are two items and two conversions, so the output might look something like this:

```
Hello, merlyn; your password expires in 3 days!
```

There are many possible `printf` conversions, so we'll take time here to describe just the most common ones. Of course, the full details are available in the [perlfunc documentation](#).

To print a number in what's generally a good way, use `%g`, which automatically chooses floating-point, integer, or even exponential notation, as needed:

```
printf "%g %g %g\n", 5/2, 51/17, 51 ** 17; # 2.5 3 1.0683e+29
```

The `%d` format means a decimal integer, truncated as needed:

```
printf "in %d days!\n", 17.85; # in 17 days!
```

Note that this is truncated, not rounded; you'll see how to round off a number in a moment.

There's also `%x` for hexadecimal and `%o` for octal if you need those:

```
printf "in 0x%x days!\n", 17; # in 0x11 days!
printf "in 0%o days!\n", 17; # in 021 days!
```

In Perl, you most often use `printf` for columnar data, since most formats accept a field width. If the data won't fit, the field will generally be expanded as needed:

```
printf "%6d\n", 42; # output like ````42 (the ` symbol stands
for a space)
printf "%2d\n", 2e3 + 1.95; # 2001
```

The `%s` conversion means a string, so it effectively interpolates the given value as a string but with a given field width:

```
printf "%10s\n", "wilma"; # looks like `    `wilma
```

A negative field width is left-justified (in any of these conversions):

```
printf "%-15s\n", "flintstone"; # looks like flintstone`    `
```

The `%f` conversion (floating-point) rounds off its output as needed, and even lets you request a certain number of digits after the decimal point:

```
printf "%12f\n", 6 * 7 + 2/3; # looks like `    `42.666667
printf "%12.3f\n", 6 * 7 + 2/3; # looks like `    `42.667
printf "%12.0f\n", 6 * 7 + 2/3; # looks like `    `43
```

To print a real percent sign, use `%%`, which is special in that it uses no element from the list:

```
printf "Monthly interest rate: %.2f%%\n",
    5.25/12; # the value looks like "0.44%"
```

Maybe you thought you could simply put a backslash in front of the percent sign. Nice try, but no. The reason that won't work is that the format is an *expression*, and the expression `"\%"` means the one-character string `'%'`. Even if we got a backslash into the format string, `printf` wouldn't know what to do with it.

So far, you've specified the width of a field by putting it directly in the format string. You can also specify it as one of the arguments. A `*` inside the format string takes the next argument as a width:

```
printf "%*s", 10, "wilma"; # looks like `    `wilma
```

You can use two `*` to get the total width and the number of decimal places to format a float:

```
printf "%*.f", 6, 2, 3.1415926; # looks like ``3.14
printf "%*.f", 6, 3, 3.1415926; # looks like `3.142
```

There's quite a bit more that you can do; see the `sprintf` documentation in [perlfunc](#).

Arrays and printf

Generally, you won't use an array as an argument to `printf`. That's because an array may hold any number of items, and a given format string will work with only a certain fixed number of items.

But there's no reason you can't whip up a format string on the fly, since it may be any expression. This can be tricky to get right, though, so it may be handy (especially when debugging) to store the format in a variable:

```
my @items = qw( wilma dino pebbles );
my $format = "The items are:\n" . ("%10s\n" x @items);
## print "the format is >>$format<<\n"; # for debugging
printf $format, @items;
```

This uses the `x` operator (which you learned about in [Chapter 2](#)) to replicate the given string the number of times given by `@items` (which is being used in a scalar context). In this case, that's 3, since there are three items, so the resulting format string is the same as if you wrote it as `"The items are:\n%10s\n%10s\n%10s\n"`. And the output prints each item on its own line, right-justified in a 10-character column, under a heading line. Pretty cool, huh? But not cool enough, because you can even combine these:

```
printf "The items are:\n".("%10s\n" x @items), @items;
```

Note that here you have `@items` being used once in a scalar context, to get its length, and once in a list context, to get its contents. Context is important.

Filehandles

A *filehandle* is the name in a Perl program for an I/O connection between your Perl process and the outside world. That is, it's the name of a *connection*, not necessarily the name of a file. Indeed, Perl has mechanisms to connect a filehandle to almost anything.

Before Perl 5.6, all filehandle names were barewords, and Perl 5.6 added the ability to store a filehandle reference in a normal scalar variable. We'll show you the bareword versions first since Perl still uses those for its special filehandles, and catch up with the scalar variable versions later in this chapter.

You name these filehandles just like other Perl identifiers: letters, digits, and underscores (but not starting with a digit). The bareword filehandles don't have any prefix character, so Perl might confuse them with present or future reserved words, or with labels, which you'll see in [Chapter 10](#). Once again, as with labels, the recommendation from Larry is that you use all uppercase letters in the name of your filehandle—not only does it stand out better, but it also guarantees that your program won't fail when Perl introduces a future (always lowercase) reserved word.

But there are also six special filehandle names that Perl already uses for its own purposes: `STDIN`, `STDOUT`, `STDERR`, `DATA`, `ARGV`, and `ARGVOUT`. Although you may choose any filehandle name you like, you shouldn't choose one of those six unless you intend to use that one's special properties.

Maybe you recognized some of those names already. When your program starts, `STDIN` is the filehandle naming the connection between the Perl process and wherever the program should get its input, known as the *standard input stream*. This is generally the user's keyboard unless the user asked for something else to be the source of input, such as a file or the output of another program through a pipe.

NOTE

The defaults for the three main I/O streams are what the Unix shells do by default. But it's not just shells that launch programs, of course. You'll see in [Chapter 15](#) what happens when you launch another program from Perl.

There's also the *standard output stream*, which is `STDOUT`. By default, this one goes to the user's display screen, but the user may send the output to a file or to another program, as you'll see shortly. These standard streams come to you from the Unix "standard I/O" library, but they work in much the same way on most modern operating systems. The general idea is that your program should blindly read from `STDIN` and blindly write to `STDOUT`, trusting in the user (or generally whichever program is starting your program) to have set those up. In that way, the user can type a command like this one at the shell prompt:

```
$ ./your_program <dino >wilma
```

That command tells the shell that the program's input should be read from the file *dino*, and the output should go to the file *wilma*. As long as the program blindly reads its input from `STDIN`, processes it (in whatever way we need), and blindly writes its output to `STDOUT`, this will work just fine.

And at no extra charge, the program will work in a *pipeline*. This is another concept from Unix, which lets us write command lines like this one:

```
$ cat fred barney | sort | ./your_program | grep something | lpr
```

Now, if you're not familiar with these Unix commands, that's OK. This line says that the *cat* command should print out all of the lines of file *fred* followed by all of the lines of file *barney*. Then that output should be the input of the *sort* command, which sorts those lines and passes them on to *your_program*. After it has done its processing, *your_program* sends the data on to *grep*, which discards certain lines in the data, sending the others

on to the *lpr* command, which should print everything that it gets on a printer. Whew!

Pipelines like that are common in Unix and many other systems today because they let you build powerful, complex commands out of simple, standard building blocks. Each building block does one thing very well, and it's your job to use them together in the right way.

There's one more standard I/O stream. If (in the previous example) *your_program* had to emit any warnings or other diagnostic messages, those shouldn't go down the pipeline. The *grep* command is set to discard anything that it hasn't specifically been told to look for, and so it will most likely discard the warnings. Even if it did keep the warnings, you probably don't want to pass them downstream to the other programs in the pipeline. So that's why there's also the *standard error stream*: `STDERR`. Even if the standard output is going to another program or file, the errors will go to wherever the user desires. By default, the errors will generally go to the user's display screen, but the user may send the errors to a file with a shell command like this one:

```
$ netstat | ./your_program 2>/tmp/my_errors
```

Generally, errors aren't buffered. That means that if the standard error and standard output streams are both going to the same place (such as the monitor), the errors may appear earlier than the normal output. For example, if your program prints a line of ordinary text, then tries to divide by zero, the output may show the message about dividing by zero first, and the ordinary text second.

Opening a Filehandle

So you've seen that Perl provides three filehandles—`STDIN`, `STDOUT`, and `STDERR`—which are automatically open to files or devices established by the program's parent process (probably the shell). When you need other filehandles, use the `open` operator to tell Perl to ask the operating system to

open the connection between your program and the outside world. Here are some examples:

```
open CONFIG, 'dino';
open CONFIG, '<dino';
open BEDROCK, '>fred';
open LOG, '>>logfile';
```

The first one opens a filehandle called `CONFIG` to a file called *dino*. That is, the (existing) file *dino* will be opened and whatever it holds will come into our program through the filehandle named `CONFIG`. This is similar to the way that data from a file could come in through `STDIN` if the command line had a shell redirection like `<dino`. In fact, the second example uses exactly that sequence. The second does the same as the first, but the less-than sign explicitly says “use this filename for input,” even though that’s the default.

This may be important for security reasons. As you’ll see in a moment (and in further detail in [Chapter 15](#)), there are a number of magical characters that may be used in filenames. If `$name` holds a user-chosen filename, simply opening `$name` will allow any of these magical characters to come into play. We recommend always using the three-argument form of `open`, which we’ll show you in a moment.

Although you don’t have to use the less-than sign to open a file for input, we include it because, as you can see in the third example, a greater-than sign means to create a new file for output. This opens the filehandle `BEDROCK` for output to the new file *fred*. Just as when the greater-than sign is used in shell redirection, we’re sending the output to a *new* file called *fred*. If there’s already a file of that name, you’re asking to wipe it out and replace it with this new one.

The fourth example shows how you may use two greater-than signs (again, as the shell does) to open a file for appending. That is, if the file already exists, you will add new data at the end. If it doesn’t exist, you will create it in much the same way as if you had used just one greater-than sign. This is handy for logfiles; your program could write a few lines to the end of a

logfile each time it's run. So that's why the fourth example names the filehandle LOG and the file *logfile*.

You can use any scalar expression in place of the filename specifier, although typically you'll want to be explicit about the direction specification:

```
my $selected_output = 'my_output';
open LOG, "> $selected_output";
```

Note the space after the greater-than sign. Perl ignores this, but it keeps unexpected things from happening if `$selected_output` were `">passwd"`, for example (which would make an append instead of a write).

In modern versions of Perl (starting with Perl 5.6), you can use a “three-argument” open:

```
open CONFIG, '<', 'dino';
open BEDROCK, '>', $file_name;
open LOG, '>>', &logfile_name();
```

The advantage here is that Perl never confuses the mode (the second argument) with some part of the filename (the third argument), which has nice advantages for security. Since they are separate arguments, Perl doesn't have a chance to get confused.

The three-argument form has another big advantage. Along with the mode, you can specify an encoding. If you know that your input file is UTF-8, you can specify that by putting a colon after the file mode and naming the encoding:

```
open CONFIG, '<:encoding(UTF-8)', 'dino';
```

If you want to write your data to a file with a particular encoding, you do the same thing with one of the write modes:

```
open BEDROCK, '>:encoding(UTF-8)', $file_name;
open LOG, '>>:encoding(UTF-8)', &logfile_name();
```

There's a shortcut for this. Instead of the full `encoding(UTF-8)`, you might sometimes see `:utf8`. This isn't really a shortcut for the full version, because it doesn't care if the input (or output) is valid UTF-8. If you use `encoding(UTF-8)`, you ensure that the data is encoded correctly. The `:utf8` takes whatever it gets and marks it as a UTF-8 string even if it isn't, which might cause problems later. Still, you might see people do something like this:

```
open BEDROCK, '>:utf8', $file_name; # probably not right
```

With the `encoding()` form, you can specify other encodings too. You can get a list of all of the encodings that your *perl* understands with a Perl one-liner:

```
$ perl -MEncode -le "print for Encode->encodings(':all')"
```

You should be able to use any of the names from that list as an encoding for reading or writing a file. Not all encodings are available on every machine, since the list depends on what you've installed (or excluded).

If you want a little-endian version of UTF-16:

```
open BEDROCK, '>:encoding(UTF-16LE)', $file_name;
```

Or perhaps Latin-1:

```
open BEDROCK, '>:encoding(iso-8859-1)', $file_name;
```

There are other *layers* that perform transformations on the input or output. For instance, you sometimes need to handle files that have DOS line endings, where each line ends with a carriage-return/linefeed (CR-LF) pair (also normally written as `"\r\n"`). Unix line endings only use the newlines. When you try to use one on the other, odd things can happen. The

:crlf encoding takes care of that. When you want to ensure that you get a CR-LF at the end of each line, you can set that encoding on the file:

```
open BEDROCK, '>:crlf', $file_name;
```

Now when you print to each line, this layer translates each newline to a CR-LF, although be careful, since if you already have a CR-LF, you'll end up with two carriage returns in a row.

You can do the same thing to read a file, which might have DOS line endings:

```
open BEDROCK, '<:crlf', $file_name;
```

Now when you read a file, Perl will translate all CR-LFs to just newlines.

Binmoding Filehandles

You don't have to know the encoding ahead of time, or even specify it if you already know it. In older Perls, if you didn't want to translate line endings, such as a random value in a binary file that happens to have the same ordinal value as the newline, you used `binmode` to turn off line-ending processing:

```
binmode STDOUT; # don't translate line endings
binmode STDERR; # don't translate line endings
```

Perl 5.6 called it a *discipline*, but that name changed in favor of *layer*.

Starting with Perl 5.6, you could specify a layer as the second argument to `binmode`. If you want to output Unicode to `STDOUT`, you want to ensure that `STDOUT` knows how to handle what it gets:

```
binmode STDOUT, ':encoding(UTF-8)';
```

If you don't do that, you might get a warning (even without turning on warnings) because `STDOUT` doesn't know how you'd like to encode it:

```
Wide character in print at test line 1.
```

You can use `binmode` with either input or output handles. If you expect UTF-8 on standard input, you can tell Perl to expect that:

```
binmode STDIN, ':encoding(UTF-8)';
```

Bad Filehandles

Perl can't actually open a file all by itself. Like any other programming language, Perl can merely ask the operating system to let us open a file. Of course, the operating system may refuse because of permission settings, an incorrect filename, or other reasons.

If you try to read from a bad filehandle (that is, a filehandle that isn't properly open or a closed network connection), you'll see an immediate end-of-file. (With the I/O methods you'll see in this chapter, end-of-file will be indicated by `undef` in a scalar context or an empty list in a list context.) If you try to write to a bad filehandle, the data is silently discarded.

Fortunately, these dire consequences are easy to avoid. First of all, if you ask for warnings with `-w` or the `warnings` pragma, Perl will generally be able to tell you with a warning when it sees that you're using a bad filehandle. But even before that, `open` always tells you if it succeeded or failed by returning `true` for success or `false` for failure. So you could write code like this:

```
my $success = open LOG, '>>', 'logfile'; # capture the return
value
if ( ! $success ) {
    # The open failed
    ...
}
```

Well, you *could* do it like that, but there's another way that you'll see in the next section.

Closing a Filehandle

When you are finished with a filehandle, you may close it with the `close` operator, like this:

```
close BEDROCK;
```

Closing a filehandle tells *perl* to inform the operating system that you're done with the given data stream, so it should write any last output data to disk in case someone is waiting for it. Perl automatically closes a filehandle if you reopen it (that is, if you reuse the filehandle name in a new `open`) or if you exit the program.

When it closes a filehandle, *perl* will flush any output buffers and release any locks on the file. Since someone else may be waiting for those things, a long-running program should generally close each filehandle as soon as possible. But many of our programs will take only one or two seconds to run to completion, so this may not matter. Closing a filehandle also releases possibly limited resources, so it's more than just being tidy.

Because of this, many simple Perl programs don't bother with `close`. But it's there if you want to be tidy, with one `close` for every `open`. In general, it's best to close each filehandle soon after you're done with it, though the end of the program often arrives soon enough.

Fatal Errors with `die`

Step aside for a moment. You need some stuff that isn't directly related to (or limited to) I/O but is more about getting out of a program earlier than normal.

When a fatal error happens inside Perl (for example, if you divide by zero, use an invalid regular expression, or call a subroutine that you haven't declared), your program stops with an error message telling why. But this functionality is available to you with the `die` function, so you can make your own fatal errors.

The `die` function prints out the message you give it (to the standard error stream, where such messages should go) and makes sure that your program exits with a nonzero exit status.

You may not have known it, but every program that runs in Unix (and many other modern operating systems) has an exit status, telling whether it was successful or not. Programs that run other programs (like the *make* utility program) look at that exit status to see that everything happened correctly. The exit status is just a single byte, so it can't say much; traditionally, it is 0 for success and a nonzero value for failure. Perhaps 1 means a syntax error in the command arguments, while 2 means that something went wrong during processing, and 3 means the configuration file couldn't be found; the details differ from one command to the next. But 0 always means that everything worked. When the exit status shows failure, a program like *make* knows not to go on to the next step.

So you could rewrite the previous example, perhaps as something like this:

```
if ( ! open LOG, '>>', 'logfile' ) {  
    die "Cannot create logfile: $!";  
}
```

If the `open` fails, `die` terminates the program and tells you that it cannot create the logfile. But what's that `$!` in the message? That's the human-readable complaint from the system. In general, when the system refuses to do something you've requested (such as opening a file), `$!` will give you a reason (perhaps "permission denied" or "file not found," in this case). This is the string that you may have obtained with `perror` in C or a similar language. This human-readable complaint message is available in Perl's special variable `$!`.

It's a good idea to include `$!` in the message when it could help the user figure out what they did wrong. But if you use `die` to indicate an error that is not the failure of a system request, don't include `$!`, since it will generally hold an unrelated message left over from something Perl did

internally. It will hold a useful value only immediately after a *failed* system request. A successful request won't leave anything useful there.

There's one more thing that `die` will do for you: it will automatically append the Perl program name and line number:

```
Cannot create logfile: permission denied at your_program line
1234.
```

That's pretty helpful—in fact, you always seem to want more information in your error messages than you included the first time around. If you don't want the line number and file revealed, make sure the dying words have a newline on the end. That is, another way you could use `die` is with a trailing newline on the message:

```
if (@ARGV < 2) {
    die "Not enough arguments\n";
}
```

If there aren't at least two command-line arguments, that program will say so and quit. It won't include the program name and line number, since the line number is of no use to the user; this is the user's error, after all. As a rule of thumb, put the newline on messages that indicate a usage error and leave it off when the error might be something you want to track down during debugging.

You should always check the return value of `open`, since the rest of the program is relying on its success.

Warning Messages with `warn`

Just as `die` can indicate a fatal error that acts like one of Perl's built-in errors (like dividing by zero), you can use the `warn` function to cause a warning that acts like one of Perl's built-in warnings (like using an `undef` value as if it were defined, when warnings are enabled).

The `warn` function works just like `die` does, except for that last step—it doesn't actually quit the program. But it adds the program name and line number if needed, and it prints the message to standard error, just as `die` would.

Automatically die-ing

Starting with v5.10, the `autodie` pragma is part of the Standard Library. So far in the examples, you checked the return value of `open` and handled the error yourself:

```
if ( ! open LOG, '>>', 'logfile' ) {  
    die "Cannot create logfile: $!";  
}
```

That can get a bit tedious if you have to do that every time you want to open a filehandle. Instead, you can use the `autodie` pragma once in your program and automatically get the `die` if your `open` fails:

```
use autodie;  
  
open LOG, '>>', 'logfile';
```

This pragma works by recognizing which Perl built-ins are system calls, which might fail for reasons beyond your program's control. When one of those system calls fails, `autodie` magically invokes the `die` on your behalf. Its error message looks close to what you might choose yourself:

```
Can't open('>>', 'logfile'): No such file or directory at test  
line 3
```

And having talked about death and dire warnings, we now return you to your regularly scheduled I/O instructional material. Read on.

Using Filehandles

Once a filehandle is open for reading, you can read lines from it just like you can read from standard input with `STDIN`. So, for example, to read lines from the Unix password file:

```
if ( ! open PASSWD, "/etc/passwd") {
    die "How did you get logged in? ($!)";
}

while (<PASSWD>) {
    chomp;
    ...
}
```

In this example, the `die` message uses parentheses around `$!`. Those are merely parentheses around the message in the output. (Sometimes a punctuation mark is just a punctuation mark.) As you can see, what we’ve been calling the “line-input operator” is really made of two components; the angle brackets (the *real* line-input operator) are around an input filehandle.

You can use a filehandle open for writing or appending with `print` or `printf`, appearing immediately after the keyword but before the list of arguments:

```
print LOG "Captain's log, stardate 3.14159\n"; # output goes to
LOG
printf STDERR "%d percent complete.\n", $done/$total * 100;
```

Did you notice that there’s no comma between the filehandle and the items to be printed? This looks especially weird if you use parentheses. Either of these forms is correct:

```
printf (STDERR "%d percent complete.\n", $done/$total * 100);
printf STDERR ("%d percent complete.\n", $done/$total * 100);
```

Changing the Default Output Filehandle

By default, if you don’t give a filehandle to `print` (or to `printf`, as everything we say here about one applies equally well to the other), the

output will go to `STDOUT`. But that default may be changed with the `select` operator. Here we'll send some output lines to `BEDROCK`:

```
select BEDROCK;
print "I hope Mr. Slate doesn't find out about this.\n";
print "Wilma!\n";
```

Once you've selected a filehandle as the default for output, it stays that way. But it's generally a bad idea to confuse the rest of the program, so you should generally set it back to `STDOUT` when you're done. Also by default, the output to each filehandle is buffered. Setting the special `$|` variable to 1 will set the currently selected filehandle (that is, the one selected at the time that the variable is modified) to always flush the buffer after each output operation. So if you wanted to be sure that the logfile gets its entries at once, in case you might be reading the log to monitor progress of your long-running program, you could use something like this:

```
select LOG;
$| = 1; # don't keep LOG entries sitting in the buffer
select STDOUT;
# ... time passes, babies learn to walk, tectonic plates shift,
# and then...
print LOG "This gets written to the LOG at once!\n";
```

Reopening a Standard Filehandle

We mentioned earlier that if you were to reopen a filehandle (that is, if you were to open a filehandle `FRED` when you've already got an open filehandle named `FRED`), the old one would be closed for you automatically. And we said that you shouldn't reuse one of the six standard filehandle names unless you intended to get that one's special features. And we also said that the messages from `die` and `warn`, along with Perl's internally generated complaints, go automatically to `STDERR`. If you put those three pieces of information together, you now have an idea about how you could send error messages to a file rather than to your program's standard error stream:

```
# Send errors to my private error log
if ( ! open STDERR, ">>/home/barney/.error_log") {
    die "Can't open error log for append: $!";
}
```

After reopening `STDERR`, any error messages from Perl go into the new file. But what happens if the `die` is executed—where will *that* message go, if the new file couldn't be opened to accept the messages?

The answer is that if one of the three system filehandles—`STDIN`, `STDOUT`, or `STDERR`—fails to reopen, Perl kindly restores the original one. That is, Perl closes the original one (of those three) only when it sees that opening the new connection is successful. Thus, this technique could be used to redirect any (or all) of those three system filehandles from inside your program, almost as if the program had been run with that I/O redirection from the shell in the first place.

Output with `say`

Perl 5.10 borrowed the `say` built-in from the ongoing development of Raku (which may have borrowed its `say` from Pascal's `println`). It's the same as `print`, although it adds a newline to the end. These forms all output the same thing:

```
use v5.10;

print "Hello!\n";
print "Hello!", "\n";
say "Hello!";
```

To just print a variable's value followed by a newline, we don't need to create an extra string or print a list. We just `say` the variable. This is especially handy in the common case of simply wanting to put a newline after whatever we want to output:

```
use v5.10;
```

```
my $name = 'Fred';  
print "$name\n";  
print $name, "\n";  
say $name;
```

To interpolate an array, we still need to quote it, though. It's the quoting that puts the spaces between the elements:

```
use v5.10;  
  
my @array = qw( a b c d );  
say @array;    # "abcd\n"  
say "@array"; # "a b c d\n";
```

Just like with `print`, we can specify a filehandle with `say`:

```
use v5.10;  
  
say BEDROCK "Hello!";
```

Since this is a Perl 5.10 feature, though, we'll only use it when we are otherwise using a Perl 5.10 feature. The old, trusted `print` is still as good as it ever was, but we suspect that there will be some Perl programmers out there who want the immediate savings of not typing the four extra characters (two in the name, plus the `\n`).

Filehandles in a Scalar

Since v5.6, you can create a filehandle in a scalar variable so that you don't have to use a bareword. This makes many things, such as passing filehandles as subroutine arguments, storing them in arrays or hashes, or controlling their scope, much easier. Although you still need to know how to use the barewords, because you'll still find them in Perl code and they are actually quite handy in short scripts where you don't benefit that much from the filehandles in a variable.

If you use a scalar variable without a value in place of the bareword in `open`, your filehandle ends up in the variable. People typically do this with

a lexical variable since that ensures that you get a variable without a value; some like to put a `_fh` on the end of these variable names to remind themselves that they are using it for a filehandle:

```
my $rocks_fh;
open $rocks_fh, '<', 'rocks.txt'
  or die "Could not open rocks.txt: $!";
```

You can even combine those two statements so that you declare the lexical variable right in the `open`:

```
open my $rocks_fh, '<', 'rocks.txt'
  or die "Could not open rocks.txt: $!";
```

Once you have the filehandle in your scalar variable, you use the variable, sigil and all, in the same place that you used the bareword version:

```
while( <$rocks_fh> ) {
    chomp;
    ...
}
```

This works for output filehandles too. You open the filehandle with the appropriate mode, then use the scalar variable in place of the bareword filehandle:

```
open my $rocks_fh, '>>', 'rocks.txt'
  or die "Could not open rocks.txt: $!";
foreach my $rock ( qw( slate lava granite ) ) {
    say $rocks_fh $rock
}

print $rocks_fh "limestone\n";
close $rocks_fh;
```

Notice that you still don't use a comma after the filehandle in these examples. Perl realizes that `$rocks_fh` is a filehandle because there's no comma after the first thing following `print`. If you put a comma after the filehandle, your output looks odd. This probably isn't what you want to do:

```
print $rocks_fh, "limestone\n"; # WRONG
```

That example produces something like this:

```
GLOB(0xABCDEF12)limestone
```

What happened? Since you used the comma after the first argument, Perl treated that first argument as a string to print instead of the filehandle. Although we don't talk about references until the next book, *Intermediate Perl*, you're seeing a *stringification* of the reference instead of using it as you probably intend. This also means that these two are subtly different:

```
print STDOUT;  
print $rocks_fh; # WRONG, probably
```

In the first case, Perl knows that `STDOUT` is a filehandle because it is a bareword. Since there are no other arguments, it uses `$_` by default. In the second one, Perl can't tell what `$rocks_fh` will have until it actually runs the statement. Since it doesn't know that it's a filehandle ahead of time, it always assumes that the `$rocks_fh` has a value you want to output. To get around this, you can always surround anything that should be a filehandle in braces to make sure that Perl does the right thing, even if you are using a filehandle that you stored in an array or a hash:

```
print { $rocks[0] } "sandstone\n";
```

When you use the braces, you don't print `$_` by default. You have to supply it yourself explicitly:

```
print { $rocks_fh } $_;
```

Depending on the sort of programming that you actually do, you might go one way or the other, choosing between bareword and scalar variable filehandles. For short programs, such as in system administration, barewords don't pose much of a problem. For big application development,

you probably want to use the lexical variables to control the scope of your open filehandles.

Exercises

See “[Answers to Chapter 5 Exercises](#)” for answers to these exercises:

1. [7] Write a program that acts like *cat* but reverses the order of the output lines. (Some systems have a utility like this named *tac*.) If you run yours as `./tac fred barney betty`, the output should be all of file *betty* from last line to first, then *barney*, and then *fred*, also from last line to first. (Be sure to use the `./` in your program’s invocation if you call it *tac* so that you don’t get the system’s utility instead!)
2. [8] Write a program that asks the user to enter a list of strings on separate lines, printing each string in a right-justified, 20-character column. To be certain that the output is in the proper columns, print a “ruler line” of digits as well. (This is simply a debugging aid.) Make sure that you’re not using a 19-character column by mistake! For example, entering `hello`, `good-bye` should give output something like this:

```
123456789012345678901234567890123456789012345678901234567
890
                                hello
                                good-bye
```

3. [8] Modify the previous program to let the user choose the column width so that entering `30`, `hello`, `good-bye` (on separate lines) would put the strings at the 30th column. (Hint: see “[Interpolation of Scalar Variables into Strings](#)”, about controlling variable interpolation.) For extra credit, make the ruler line longer when the selected width is larger.

Chapter 6. Hashes

In this chapter, you will see a feature that makes Perl one of the world's truly great programming languages: *hashes*. Although hashes are a powerful and useful feature, you may have used other powerful languages for years without ever hearing of hashes. But you'll use hashes in nearly every Perl program you write from now on; they're that important.

What Is a Hash?

A hash is a data structure, not unlike an array in that it can hold any number of values and retrieve them at will. But instead of indexing the values by *number*, as you did with arrays, you look up hash values by *name*. That is, the indices, called *keys*, aren't numbers but instead are arbitrary, unique strings (see [Figure 6-1](#)).

Hash keys are strings, first of all, so instead of getting element number 3 from an array, you access the hash element named `wilma`, for instance.

These keys are arbitrary strings—you can use any string expression for a hash key. And they are unique strings—just as there's only one array element numbered 3, there's only one hash element named `wilma`.

Another way to think of a hash is that it's like a barrel of data, where each piece of data has a tag attached. You can reach into the barrel and pull out any tag and see what piece of data is attached. But there's no “first” item in the barrel; it's just a jumble. In an array, you start with element 0, then element 1, then element 2, and so on. But in a hash there's no fixed order, no first element. It's just a collection of key-value pairs.

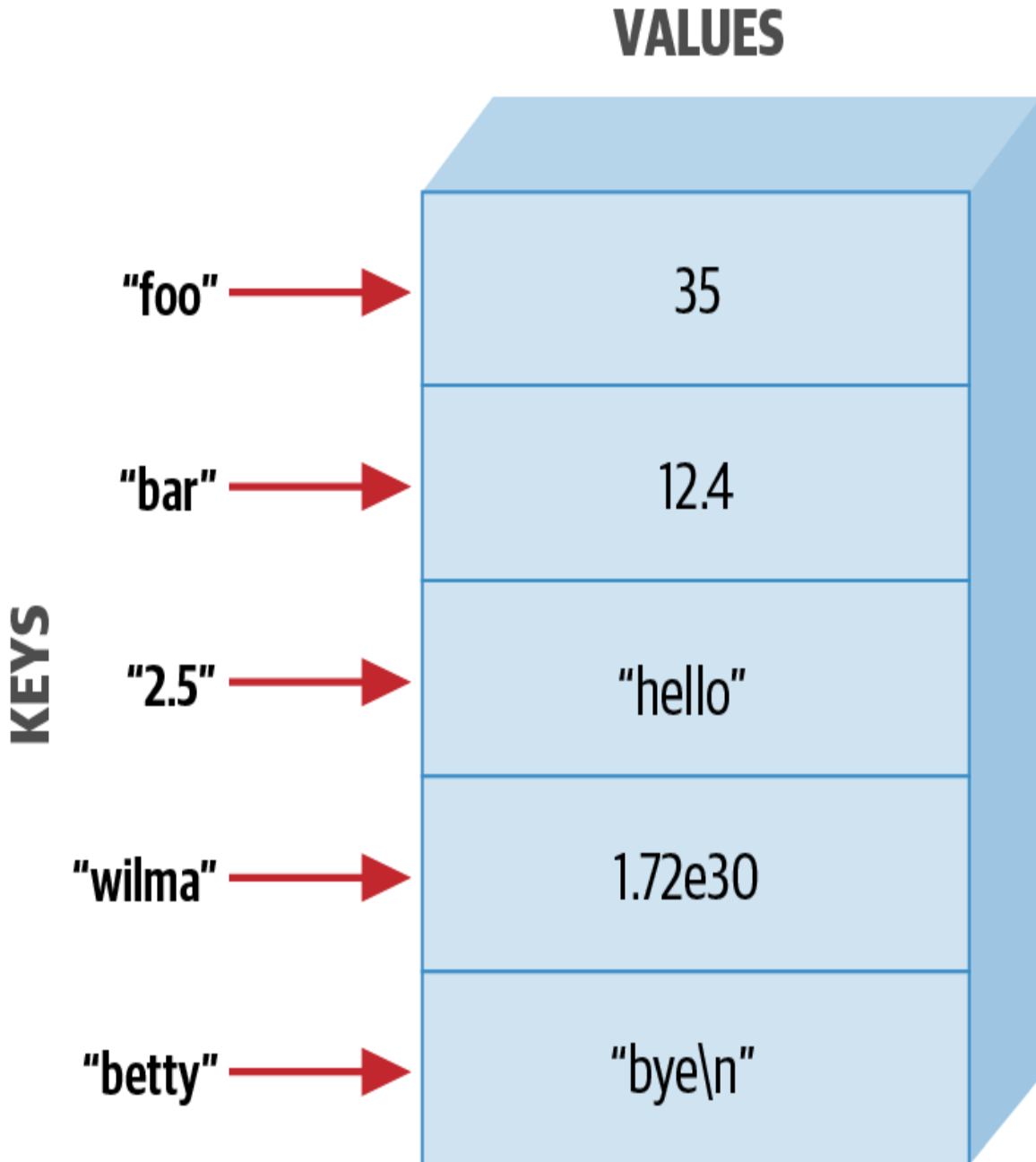


Figure 6-1. Hash keys and values

The keys and values are both arbitrary scalars, but the keys are always converted to strings. So, if you used the numeric expression $50/20$ as the key, it would be turned into the three-character string "2.5", which is one of the keys shown in [Figure 6-2](#).

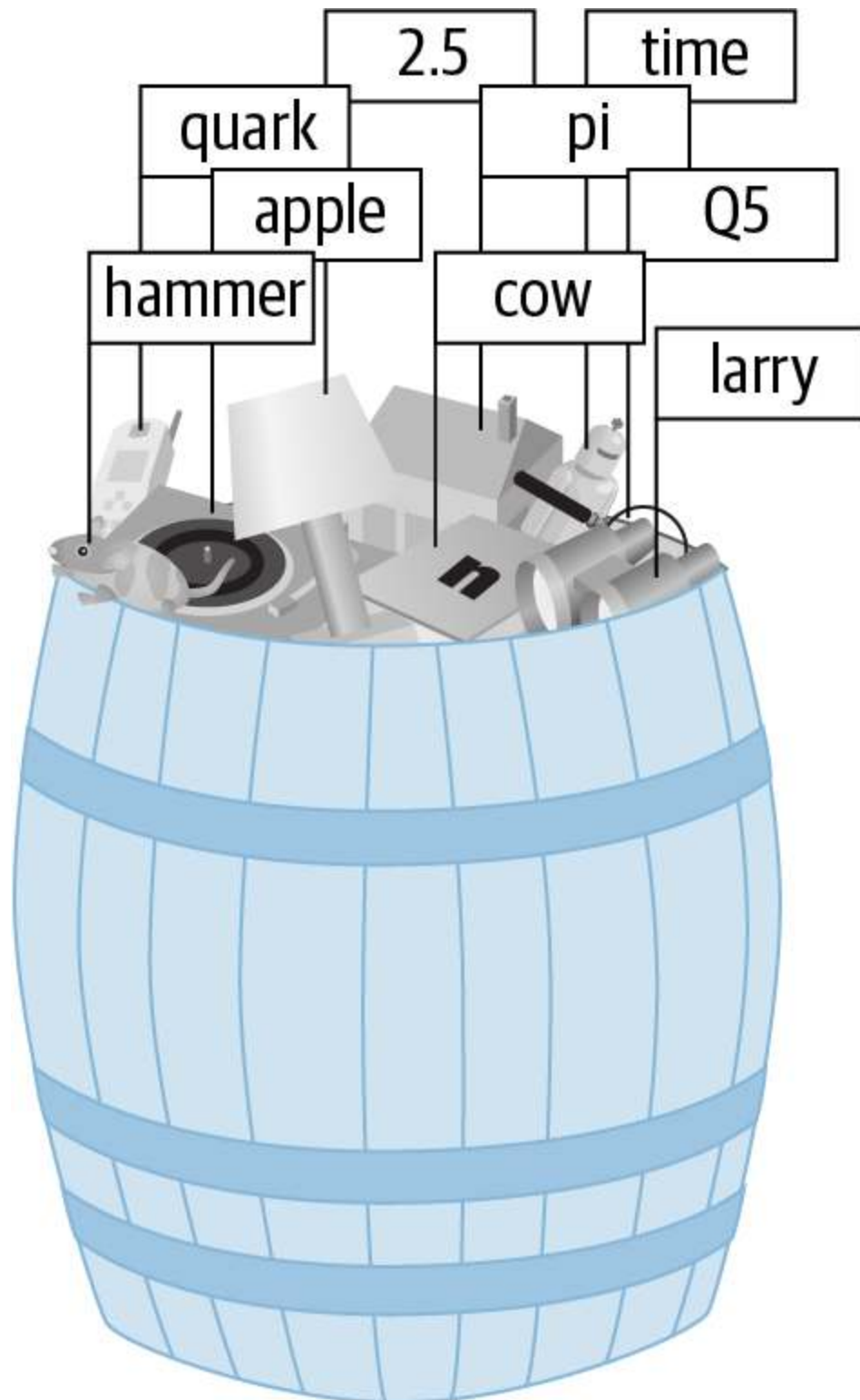


Figure 6-2. A hash as a barrel of data

As usual, Perl's “no unnecessary limits” philosophy applies: a hash may be of any size, from an empty hash with zero key-value pairs, up to whatever

fills up your memory.

Some implementations of hashes (such as in the original *awk* language, where Larry borrowed the idea from) slow down as the hashes get larger and larger. This is not the case in Perl—it has a good, efficient, scalable algorithm. So, if a hash has only three key-value pairs, it’s very quick to “reach into the barrel” and pull out any one of those. If the hash has three *million* key-value pairs, it should be just about as quick to pull out any one of those. A big hash is nothing to fear.

It’s worth mentioning again that the keys are always unique, although you may use the same value more than once. The values of a hash may be all numbers, all strings, `undef` values, or a mixture. But the keys are all arbitrary, unique strings.

Why Use a Hash?

When you first hear about hashes, especially if you’ve lived a long and productive life as a programmer using languages that don’t have hashes, you may wonder why anyone would want one of these strange beasts. Well, the general idea is that you’ll have one set of data “related to” another set of data. For example, here are some hashes you might find in typical applications of Perl:

Driver’s license number, name

There may be many, many people named John Smith, but you hope that each one has a different driver’s license number. That number makes for a unique key, and the person’s name is the value.

Word, count of number of times that word appears

This is a very common use of a hash. It’s so common, in fact, that it just might turn up in the exercises at the end of the chapter!

The idea here is that you want to know how often each word appears in a given document. Perhaps you’re building an index to a number of documents so that when a user searches for `fred`, you’ll know that a

certain document mentions `fred` five times, another mentions `fred` seven times, and yet another doesn't mention `fred` at all—so you'll know which documents the user is likely to want. As the index-making program reads through a given document, each time it sees a mention of `fred`, it adds one to the value filed under the key of `fred`. That is, if you had seen `fred` twice already in this document, the value would be 2, but now you increment it to 3. If you had not yet seen `fred`, you change the value from `undef` (the implicit, default value) to 1.

Username, number of disk blocks they are using (wasting)

System administrators like this one: the usernames on a given system are all unique strings, so they can be used as keys in a hash to look up information about that user.

Yet another way to think of a hash is as a *very* simple database, in which just one piece of data may be filed under each key. In fact, if your task description includes phrases like “finding duplicates,” “unique,” “cross-reference,” or “lookup table,” it's likely that a hash will be useful in the implementation.

Hash Element Access

To access an element of a hash, you use syntax that looks like this:

```
$hash{$some_key}
```

This is similar to what you used for array access, but here you use curly braces instead of square brackets around the subscript (key). You do this because you're doing something fancier than ordinary array access, so you should use fancier punctuation. And that key expression is now a string rather than a number:

```
$family_name{'fred'}    = 'flintstone';  
$family_name{'barney'} = 'rubble';
```

Figure 6-3 shows how the resulting hash keys are assigned.

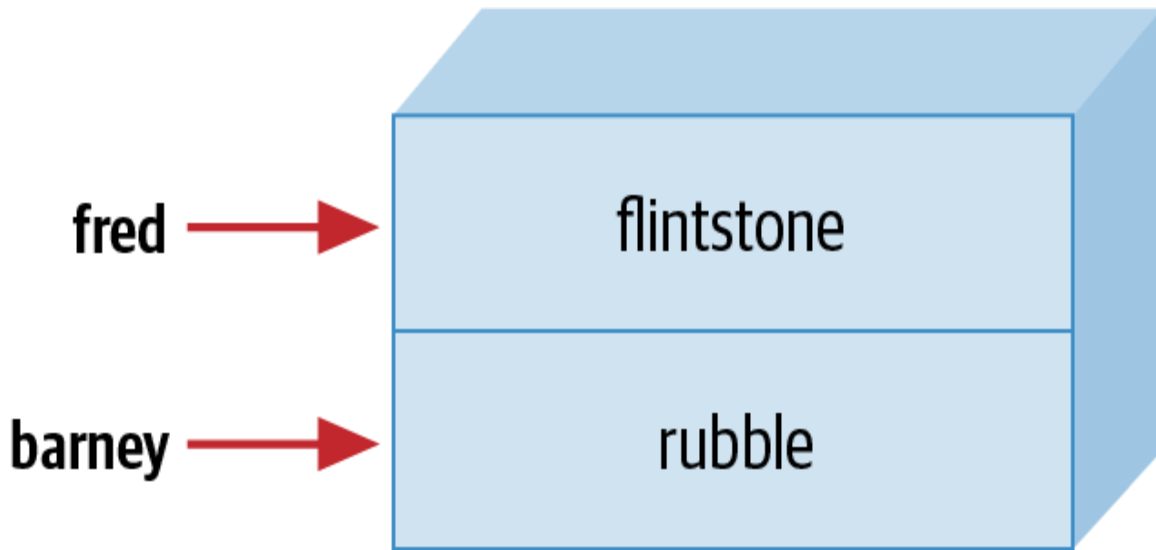


Figure 6-3. Assigned hash keys

This lets you use code like this:

```
foreach my $person (qw< barney fred >) {  
    print "I've heard of $person $family_name{$person}.\n";  
}
```

The name of the hash is like any other Perl identifier. And it's from a separate namespace; that is, there is no connection between the hash element `$family_name{"fred"}` and a subroutine `&family_name`, for example. Of course, there's no reason to confuse everyone by giving everything the same name. But Perl won't mind if you also have a scalar called `$family_name` and array elements like `$family_name[5]`. We humans will have to do as Perl does; that is, you look to see what punctuation appears before and after the identifier to see what it means. When there is a dollar sign in front of the name and curly braces afterward, you're accessing a hash element.

When choosing the name of a hash, it's often nice to think of the word *for* between the name of the hash and the key, as in “the `family_name` for fred is flintstone.” So the hash is named `family_name`. Then the relationship between the keys and their values becomes clear.

Of course, the hash key may be any expression, not just the literal strings and simple scalar variables that you're showing here:

```
$foo = 'bar';  
print $family_name{ $foo . 'ney' }; # prints 'rubble'
```

When you store something in an existing hash element, it overwrites the previous value:

```
$family_name{'fred'} = 'astaire'; # gives new value to existing  
element  
$bedrock = $family_name{'fred'}; # gets 'astaire'; old value is  
lost
```

That's analogous to what happens with arrays and scalars; if you store something new in `$pebbles[17]` or `$dino`, the old value is replaced. If you store something new in `$family_name{'fred'}`, the old value is replaced as well.

Hash elements spring into existence when you first assign to them:

```
$family_name{'wilma'} = 'flintstone'; # adds a new  
key (and value)  
$family_name{'betty'} .= $family_name{'barney'}; # creates the  
element if needed
```

This is a feature called *autovivification*, which we talk about more in *Intermediate Perl*. That's also just like what happens with arrays and scalars; if you didn't have `$pebbles[17]` or `$dino` before, you will have it after you assign to it. If you didn't have `$family_name{'betty'}` before, you do now.

And accessing outside the hash gives undef:

```
$granite = $family_name{'larry'}; # No larry here: undef
```

Once again, this is just like what happens with arrays and scalars; if there's nothing yet stored in `$pebbles[17]` or `$dino`, accessing them will

yield undef. If there's nothing yet stored in `$family_name{'larry'}`, accessing it will yield undef.

The Hash as a Whole

To refer to the entire hash, use the percent sign (%) as a prefix. So, the hash you've been using for the last few pages is actually called `%family_name`.

For convenience, you can convert a hash into a list and back again. Assigning to a hash (in this case, the one from [Figure 6-1](#)) is a list-context assignment, where the list is key-value pairs:

```
%some_hash = ('foo', 35, 'bar', 12.4, 2.5, 'hello',  
              'wilma', 1.72e30, 'betty', "bye\n");
```

Although you can use any list expression, it must have an even number of elements, because the hash is made of key-value *pairs*. An odd element will likely do something unreliable, although it's a warnable offense.

The value of the hash (in a list context) is a simple list of key-value pairs:

```
my @any_array = %some_hash;
```

Perl calls this *unwinding* the hash—turning it back into a list of key-value pairs. Of course, the pairs won't necessarily be in the same order as the original list:

```
print "@any_array\n";  
# might give something like this:  
# betty bye (and a newline) wilma 1.72e+30 foo 35 2.5 hello bar  
12.4
```

NOTE

In scalar context, a hash returns the number of keys in the hash: `my $count = %hash;`. However, before v5.26, this returned a weird fraction related to the amount of the hash you have used versus the amount *perl* has allocated.

The order is jumbled because Perl keeps the key-value pairs in an order that's convenient for Perl so that it can look up any item quickly. You use a hash either when you don't care what order the items are in, or when you have an easy way to put them into the order you want.

Of course, even though the order of the key-value pairs is jumbled, each key “sticks” with its corresponding value in the resulting list. So, even though you don't know where the key `foo` will appear in the list, you know that its value, `35`, will be right after it.

Hash Assignment

It's rare to do so, but you can copy a hash using the obvious syntax of simply assigning one hash to another:

```
my %new_hash = %old_hash;
```

This is actually more work for Perl than meets the eye. Unlike what happens in languages like Pascal or C, where such an operation would be a simple matter of copying a block of memory, Perl's data structures are more complex. So, that line of code tells Perl to unwind the `%old_hash` into a list of key-value pairs, then assign those to `%new_hash`, building it up one key-value pair at a time.

It's more common to transform the hash in some way, though. For example, you could make an inverse hash:

```
my %inverse_hash = reverse %any_hash;
```


This takes `%any_hash` and unwinds it into a list of key-value pairs, making a list like *(key, value, key, value, key, value, ...)*. Then `reverse` turns that list end for end, making a list like *(value, key, value, key, value, key, ...)*. Now the keys are where the values used to be, and the values are where the keys used to be. When you store that in `%inverse_hash`, you can look up a string that was a value in `%any_hash`—it’s now a key of `%inverse_hash`. And the value you find is one of the keys from `%any_hash`. So, you have a way to look up a “value” (now a key), and find a “key” (now a value).

Of course, you might guess (or determine from scientific principles, if you’re clever) that this will work properly only if the values in the original hash were unique—otherwise, you’d have duplicate keys in the new hash, and keys are always unique. Here’s the rule that Perl uses: the last one in, wins. That is, the later items in the list overwrite any earlier ones.

Of course, you don’t know what order the key-value pairs will have in this list, so there’s no telling which ones would win. You’d use this technique only if you know there are no duplicates among the original values. But that’s the case for the IP address and hostname examples given earlier:

```
%ip_address = reverse %host_name;
```

Now you can look up a hostname or IP address with equal ease to find the corresponding IP address or hostname.

The Big Arrow

When assigning a list to a hash, sometimes it’s not obvious which elements are keys and which are values. For example, in this assignment (which you saw earlier), we humans have to count through the list, saying “key, value, key, value...” in order to determine whether `2.5` is a key or a value:

```
%some_hash = ('foo', 35, 'bar', 12.4, 2.5, 'hello',  
              'wilma', 1.72e30, 'betty', "bye\n");
```

Wouldn't it be nice if Perl gave you a way to pair up keys and values in that kind of a list so that it would be easy to see which ones were which? Larry thought so, which is why he invented the big arrow (`=>`). To Perl, it's just a different way to "spell" a comma, so it's also sometimes called the "fat comma." That is, in the Perl grammar, any time you need a comma (`,`), you can use the big arrow instead; it's all the same to Perl. So here's another way to set up the hash of last names:

```
my %last_name = ( # a hash may be a lexical variable
    'fred'    => 'flintstone',
    'dino'    => undef,
    'barney'  => 'rubble',
    'betty'   => 'rubble',
);
```

Here, it's easy (or perhaps easier, at least) to see whose name pairs with which value, even if we end up putting many pairs on one line. And notice that there's an extra comma at the end of the list. As we saw earlier, this is harmless but convenient; if we need to add additional people to this hash, we'll simply make sure that each line has a key-value pair and a trailing comma. Perl will see that there is a comma between each item and the next, and one extra (harmless) comma at the end of the list.

It gets better, though. Perl offers many shortcuts that can help the programmer. Here's a handy one: you may omit the quote marks on some hash keys when you use the fat comma, which automatically quotes the values to its left:

```
my %last_name = (
    fred    => 'flintstone',
    dino    => undef,
    barney  => 'rubble',
    betty   => 'rubble',
);
```

Of course, you can't omit the quote marks on just *any* key, since a hash key may be any arbitrary string. If that value on the left looks like a Perl

operator, Perl can get confused. This won't work because Perl thinks the + is the addition operator, not a string to quote:

```
my %last_name = (  
    +    => 'flintstone',    # WRONG! Compilation error!  
);
```

But keys are often simple. If the hash key is made up of nothing but letters, digits, and underscores (without starting with a digit), you *may* be able to omit the quote marks. This kind of simple string without quote marks is called a *bareword*, since it stands alone without quotes.

Another place you are permitted to use this shortcut is the most common place a hash key appears: in the curly braces of a hash element reference. For example, instead of `$score{ 'fred' }`, you could write simply `$score{fred}`. Since many hash keys are simple like this, not using quotes is a real convenience. But beware; if there's anything inside the curly braces besides a bareword, Perl will interpret it as an expression. For instance, if there is a `.`, Perl interprets it as a string concatenation:

```
$hash{ bar.foo } = 1;    # that's the key 'barfoo'
```

Hash Functions

Naturally, there are some useful functions that can work on an entire hash at once.

The keys and values Functions

The `keys` function yields a list of all the keys in a hash, while the `values` function gives the corresponding values. If there are no elements to the hash, then either function returns an empty list:

```
my %hash = ('a' => 1, 'b' => 2, 'c' => 3);  
my @k = keys %hash;  
my @v = values %hash;
```

So, `@k` will contain `'a'`, `'b'`, and `'c'`, and `@v` will contain 1, 2, and 3—in *some* order. Remember, Perl doesn't maintain the order of elements in a hash. But whatever order the keys are in, the values are in the corresponding order: if `'b'` is last in the keys, 2 will be last in the values; if `'c'` is the first key, 3 will be the first value. That's true as long as you don't modify the hash between the request for the keys and the one for the values. If you add elements to the hash, Perl reserves the right to rearrange it as needed, to keep the access quick. In a scalar context, these functions give the number of elements (key-value pairs) in the hash. They do this quite efficiently, without having to visit each element of the hash:

```
my $count = keys %hash; # gets 3, meaning three key-value pairs
```

Once in a long while, you'll see that someone has used a hash as a Boolean (true/false) expression, something like this:

```
if (%hash) {  
    print "That was a true value!\n";  
}
```

That will be true if (and only if) the hash has at least one key-value pair. So, it's just saying, "If the hash is not empty...." But this is a pretty rare construct, as such things go. The actual result is the number of keys (v5.26 and later) or the internal debugging string useful to the people who maintain Perl (prior to v5.26). It used to look something like "4/16," but either version of the value is guaranteed to be true when the hash is nonempty and false when it's empty, so the rest of us can still use it for that.

The each Function

If you wish to iterate over (that is, examine every element of) an entire hash, one of the usual ways is to use the `each` function, which returns a key-value pair as a two-element list. On each evaluation of this function for the same hash, the next successive key-value pair is returned, until you have

accessed all the elements. When there are no more pairs, `each` returns an empty list.

In practice, the only way to use `each` is in a `while` loop, something like this:

```
while ( ($key, $value) = each %hash ) {  
    print "$key => $value\n";  
}
```

There's a lot going on here. First, `each %hash` returns a key-value pair from the hash, as a two-element list; let's say the key is `"c"` and the value is 3, so the list is `("c", 3)`. That list is assigned to the list `($key, $value)`, so `$key` becomes `"c"` and `$value` becomes 3.

But that list assignment is happening in the conditional expression of the `while` loop, which is a scalar context. (Specifically, it's a Boolean context, looking for a true/false value; and a Boolean context is a particular kind of scalar context.) The value of a list assignment in a scalar context is the number of elements in the source list—2, in this case. Since 2 is a true value, you enter the body of the loop and print the message `c => 3`.

The next time through the loop, `each %hash` gives a new key-value pair; say it's `("a", 1)` this time. (It knows to return a different pair than previously because it keeps track of where it is; in technical jargon, there's an iterator stored in each hash.) Those two items are stored in `($key, $value)`. Since the number of elements in the source list was again 2, a true value, the `while` condition is true, and the loop body runs again, telling us `a => 1`.

NOTE

Each hash has its own private iterator. Loops using `each` may be nested as long as they are iterating over *different* hashes. Different calls to `each` on the same hash will probably give you unexpected results since they interfere with each other.

You go one more time through the loop, and by now you know what to expect, so it's no surprise to see `b => 2` appear in the output.

But you knew it couldn't go on forever. Now, when Perl evaluates each `%hash`, there are no more key-value pairs available, so each has to return an empty list. The empty list is assigned to `($key, $value)`, so `$key` gets `undef` and `$value` also gets `undef`.

But that hardly matters, because you're evaluating the whole thing in the conditional expression of the `while` loop. The value of a list assignment in a scalar context is the number of elements in the source list—in this case, that's 0. Since 0 is a false value, the `while` loop is done, and execution continues with the rest of the program.

Of course, each returns the key-value pairs in a jumbled order. (It's the same order as `keys` and `values` would give, incidentally—the “natural” order of the hash.) If you need to go through the hash in order, simply sort the keys, perhaps something like this:

```
foreach $key (sort keys %hash) {  
    $value = $hash{$key};  
    print "$key => $value\n";  
    # Or, we could have avoided the extra $value variable:  
    # print "$key => $hash{$key}\n";  
}
```

We'll see more about sorting hashes in [Chapter 14](#).

Typical Use of a Hash

At this point, you may find it helpful to see a more concrete example.

The Bedrock Library uses a Perl program in which a hash keeps track of how many books each person has checked out, among other information:

```
$books{'fred'} = 3;  
$books{'wilma'} = 1;
```

It's easy to see whether an element of the hash is true or false; do this:

```
if ($books{$someone}) {  
    print "$someone has at least one book checked out.\n";  
}
```

But there are some elements of the hash that aren't true:

```
$books{"barney"} = 0;          # no books currently checked out  
$books{"pebbles"} = undef;    # no books EVER checked out; a new  
library card
```

Since Pebbles has never checked out any books, her entry has the value of `undef` rather than `0`.

There's a key in the hash for everyone who has a library card. For each key (that is, for each library patron), there's a value that is either a number of books checked out, or `undef` if that person's library card has never been used.

The exists Function

To see whether a key exists in the hash (that is, whether someone has a library card or not), use the `exists` function, which returns a true value if the given key exists in the hash, whether the corresponding value is true or not:

```
if (exists $books{"dino"}) {  
    print "Hey, there's a library card for dino!\n";  
}
```

That is to say, `exists $books{"dino"}` will return a true value if (and only if) `dino` is found in the list of keys from `keys %books`.

The delete Function

The `delete` function removes the given key (and its corresponding value) from the hash (if there's no such key, its work is done; there's no warning or

error in that case):

```
my $person = "betty";
delete $books{$person}; # Revoke the library card for $person
```

Note that this is *not* the same as storing `undef` in that hash element—in fact, it’s precisely the opposite! Checking `exists($books{"betty"})` will give opposite results in these two cases; after a `delete`, the key *can’t* exist in the hash, but after storing `undef`, the key *must* exist.

In the example, `delete` versus storing `undef` is the difference between taking away Betty’s library card versus giving her a card that has never been used.

Hash Element Interpolation

You can interpolate a single hash element into a double-quoted string just as you’d expect:

```
foreach $person (sort keys %books) {           # each patron,
in order
    if ($books{$person}) {
        print "$person has $books{$person} items\n"; # fred has 3
items
    }
}
```

But there’s no support for entire hash interpolation; `"%books"` is just the six characters of (literally) `%books`. So you’ve seen all of the magical characters that need backslashing in double quotes: `$` and `@`, because they introduce a variable that Perl will try to interpolate; `"`, since that’s the quoting character that would otherwise end the double-quoted string; and `\`, the backslash itself. Any other characters in a double-quoted string are nonmagical and should simply stand for themselves. But do beware of the apostrophe (`'`), left square bracket (`[`), left curly brace (`{`), small arrow (`-`

>), or double colon (: :) following a variable name in a double-quoted string, as they could perhaps mean something you didn't intend.

The %ENV Hash

There's a hash that you can use right away. Your Perl program, like any other program, runs in a certain *environment*, and your program can look at the environment to get information about its surroundings. Perl stores this information in the %ENV hash. For instance, you'll probably see a PATH key in %ENV:

```
print "PATH is $ENV{PATH}\n";
```

Depending on your particular setup and operating system, you'll see something like this:

```
PATH is /usr/local/bin:/usr/bin:/sbin:/usr/sbin
```

Most of these are set for you automatically, but you can add to the environment yourself. How you do this depends on your operating system and shell. For Bash, you'd use `export`:

```
$ export CHARACTER=Fred
```

For Windows, you'd use `set`:

```
C:\> set CHARACTER=Fred
```

Once you set these environment variables outside your Perl program, you can access them inside your Perl program:

```
print "CHARACTER is $ENV{CHARACTER}\n";
```

You'll see more about %ENV in [Chapter 15](#).

Exercises

See “[Answers to Chapter 6 Exercises](#)” for answers to these exercises:

1. [7] Write a program that will ask the user for a given name and report the corresponding family name. Use the names of people you know, or (if you spend so much time on the computer that you don’t know any actual people) use the following table:

Input	Output
fred	flintstone
barney	rubble
wilma	flintstone

2. [15] Write a program that reads a series of words (with one word per line) until end-of-input, then prints a summary of how many times each word was seen. (Hint: remember that when an undefined value is used as if it were a number, Perl automatically converts it to 0. It may help to look back at the earlier exercise that kept a running total.) So, if the input words were `fred`, `barney`, `fred`, `dino`, `wilma`, `fred` (all on separate lines), the output should tell us that `fred` was seen 3 times. For extra credit, sort the summary words in code point order in the output.
3. [15] Write a program to list all of the keys and values in `%ENV`. Print the results in two columns in ASCIIbetical order. For extra credit, arrange the output to vertically align both columns. The `length` function can help you figure out how wide to make the first column. Once you get the program running, try setting some new environment variables and ensuring that they show up in your output.

Chapter 7. Regular Expressions

Perl has strong support for regular expressions, or *regexes* for short. This mini-language within Perl is a tight and powerful way to describe a family of strings that can match a pattern. It's one of the features that has made Perl so popular.

Today many languages have some sort of access to these powerful tools (perhaps as something called “Perl-Compatible Regular Expressions,” or PCRE), but Perl is still out in front of most of them in its power and expressivity.

In the next three chapters, we will show you most of the regex features that you'll use in most programs. In this chapter, we'll show you the basics of the regular expression syntax. In [Chapter 8](#), we show you the match operator and more sophisticated ways to employ patterns. Finally, in [Chapter 9](#), we show you ways to use patterns to modify text.

Regexes will probably become one of your favorite parts of the language, at least for a while. But since regular expressions are tight and compact, they may also frustrate you to no end until you get used to them. That's normal. As you go through these chapters, try the examples as you read them. The more complex patterns build on what you've read earlier.

Sequences

Perl's regular expressions either match a string or they don't. There is no such thing as a partial match. And Perl doesn't look for a best match. Instead, it matches the leftmost, longest substring that satisfies the pattern.

NOTE

Some regular expression engines in other languages work differently, perhaps even looking for a “better” match *after* they find one that fits. See Jeffrey Friedl’s *Mastering Regular Expressions* for the gory details.

The simplest sort of pattern is a *sequence*. You put literal characters next to each other to assert that you want to match a substring with those characters in that order. If you want to match the sequence `abba`, you put that between slashes:

```
$_ = "yabba dabba doo";  
if (/abba/) {  
    print "It matched!\n";  
}
```

The forward slashes in the `if` expression are the match operator. It applies its pattern to the string in `$_`. The pattern is the part between the slashes. This might seem weird because this is the first time in this book that you’ve seen an operator that surrounds the value.

If the pattern matches the string in `$_`, the match operator returns true. Otherwise, it returns false. The match works by trying the pattern at the first position in the string. The first character in `$_` is a `y`, but the first character in the pattern is `a`. Those don’t match, so Perl keeps looking.

The match operator then slides over one spot and tries the match at the next position, as shown in **Figure 7-1**. It matches the `a`—so far, so good. It tries to match the next character in the sequence, the `b`. It matches the first `b` in the string. Again, so far, so good. Then it matches the second `b`, and finally the last `a`. The match operator found the sequence in the string, so the pattern matches.

yabba dabba do
/abba/ no match

yabba dabba do
/abba/ move over one, match!

Figure 7-1. The pattern moves along the string looking for a match

Once the pattern is successful, the match operator returns true. This process matched the leftmost possible place to match. It doesn't need to find the second match within dabba because it already knows the string matches (although we'll show global matching in [Chapter 8](#)).

Inside a Perl pattern, whitespace is significant. Any whitespace you include in the pattern tries to match the same whitespace in `$_`. This example doesn't match because it looks for a space between the two bs:

```
$_ = "yabba dabba doo";  
if (/ab ba/) { # Won't match  
    print "It matched!\n";  
}
```

This pattern matches because the string in `$_` has a space between the ba and da:

```
$_ = "yabba dabba doo";  
if (/ba da/) { # Does match  
    print "It matched!\n";  
}
```

The pattern in the match operator is a double-quoted context; you can do the same sorts of things you can do in a double-quoted string. The special sequences such as `\t` and `\n` mean tab and newline just like they do in a double-quoted string. There are many ways to match a tab character:

<code>/coke\tsprite/</code>	<code># \t for tab</code>
<code>/coke\N{CHARACTER TABULATION}sprite/</code>	<code># \N{charname}</code>
<code>/coke\011sprite/</code>	<code># character number, octal</code>
<code>/coke\x09sprite/</code>	<code># character number, hex</code>
<code>/coke\x{9}sprite/</code>	<code># character number, hex</code>
<code>/coke\${tab}sprite/</code>	<code># scalar variable</code>

Perl first interpolates everything into the pattern and then compiles the pattern. If the pattern isn't a valid regex, you'll get an error. For example, a pattern with a single opening parenthesis is not valid (you'll see why later in this chapter):

```
$pattern = "(";
if (/ $pattern/) {
    print "It matched!\n";
}
```

There's a pattern that matches every string. You can have the sequence of zero characters just like you can have the empty string:

```
$_ = "yabba dabba doo";
if (//) {
    print "It matched!\n";
}
```

If you follow the leftmost, longest rule, you'll work out that the empty pattern matches at the beginning of the string where it always finds the sequence of zero characters.

Practice Some Patterns

Now that you know the simplest form of regular expressions, you should try some yourself (especially if you've never used regular expressions). You'll learn more by trying them yourself than merely reading about them.

You know enough Perl to write a simple pattern tester now. You should replace the `PATTERN_GOES_HERE` with the pattern you'd like to test:

```

while( <STDIN> ) {
    chomp;
    if ( /PATTERN_GOES_HERE/ ) {
        print "\tMatches\n";
    }
    else {
        print "\tDoesn't match\n";
    }
}

```

Let's suppose that you want to test for `fred`. Change the pattern in the program:

```

while( <STDIN> ) {
    chomp;
    if ( /fred/ ) {
        print "\tMatches\n";
    }
    else {
        print "\tDoesn't match\n";
    }
}

```

When you run this program, it waits for input. For each line you enter, it tries the match and prints the result:

```

$ perl try_a_pattern
Capitalized Fred should not match
    Doesn't match
Lowercase fred should match
    Matches
Barney will not match
    Doesn't match
Neither will Frederick
    Doesn't match
But Alfred will
    Matches

```

NOTE

Some IDEs come with tools that help you build and test a regular expression. There are many online tools that do the same, such as regexr.com.

Note that the input line with a capitalized F does not match. We haven't shown you a way to make a pattern case-insensitive yet. Also note that the fred in Alfred matches even though it's in the middle of a larger word. Later you'll see how to fix that too.

You have to change the program every time you want to try a new pattern. That's an annoying way to program. Since you can interpolate a variable into a pattern, you can take the first argument from the command line as the pattern:

```
while( <STDIN> ) {
    chomp;
    if ( /$ARGV[0]/ ) { # May be hazardous for your health
        print "\tMatches\n";
    }
    else {
        print "\tDoesn't match\n";
    }
}
```

This is a slightly hazardous way to program since that argument could be anything and Perl has regex features to execute arbitrary code. For our purposes of testing simple regular expressions, we can take the hazard. Note that your shell may require you to quote the pattern since some of the regex characters may be special shell characters too:

```
$ perl try_a_pattern "fred"
This will match fred
Matches
But not Barney
Doesn't match
```

You can run it with a different pattern without changing the program:

```
$ perl try_a_pattern "barney"
This will match fred (not)
Doesn't match
But it will match barney
Matches
```


Again, this is slightly hazardous and we don't endorse this for production code. For this chapter, however, it does a decent job. As you go through this chapter, you may want to use this program to try new patterns as we introduce them. Try the examples as you run into them; your comfort with regexes comes with practice!

The Wildcard

The dot, `.`, matches any single character except a newline. It's the first regex *metacharacter* we show:

```
$_ = "yabba dabba doo";
if (/ab.a/) {
    print "It matched!\n";
}
```

That single exception, the newline, might seem weird. Perl considers the common case where you read a line of input and want to match against that string. In that case, the trailing newline is merely the line separator and not an interesting part of the string.

Inside the pattern, the dot is not a literal character. Sometimes you might miss this because the metacharacter also matches the literal version. This matches because the dot wildcard can match the `!` at the end of the string:

```
$_ = "yabba dabba doo!";
if (/doo./) {                # matches
    print "It matched!\n";
}

$_ = "yabba dabba doo\n";
if (/doo./) {                # doesn't match
    print "It matched!\n";
}
```

If you want to match an actual dot, you need to escape it with the backslash:

```
$_ = "yabba dabba doo.";
if (/doo\./) {                # matches
    print "It matched!\n";
}
```

The backslash is the second metacharacter (and we’ll stop counting now). This means to match a literal backslash, you have to escape that too:

```
$_ = 'a real \\ backslash';
if (/\\\/) {                  # matches
    print "It matched!\n";
}
```

Perl v5.12 added another way to write “any character except a newline.” If you don’t like the dot, you can use `\N`:

```
$_ = "yabba dabba doo!";
if (/doo\N/) {                # matches
    print "It matched!\n";
}

$_ = "yabba dabba doo\n";
if (/doo\N/) {                # doesn't match
    print "It matched!\n";
}
```

You’ll see more about the `\N` in “**Character Class Shortcuts**”.

Quantifiers

You can repeat parts of a pattern with a *quantifier*. These metacharacters apply to the part of the pattern that comes directly before them. Some people call these *repeat* or *repetition* operators.

The easiest quantifier is the question mark, `?`. It asserts that the preceding item shows up zero or one times (or, in human speak, that item is optional). Suppose that some people write `Bamm-bamm` while others write `Bambamm` without the hyphen. You can match either by making the `-` optional:

```

$_ = 'Bamm-bamm';
if (/Bamm-?bamm/) {
    print "It matched!\n";
}

```

Try it with your test program using different ways to type Bamm-Bamm's name:

```

$ perl try_a_pattern "Bamm-?bamm"
Bamm-bamm
    Matches
Bammbamm
    Matches
Are you Bammbamm or Bamm-bamm?
    Matches

```

In that last line, which version of Bamm-Bamm's name matches? Perl starts at the left and shifts the pattern along the string until it matches. The first possible match is Bammbamm. Once Perl matches that, it stops, even though there is a longer possible match later in the string. Perl matches the leftmost substring; it doesn't even know about the later one because it didn't have to look that far ahead to know the string matched.

The next quantifier is the star, `*`. It asserts that the preceding item shows up zero or more times. That seems like a weird way to say it, but it means it can be there or not. It's optional, but it can be there as many times as it likes:

```

$_ = 'Bamm-----bamm';
if (/Bamm-*bamm/) {
    print "It matched!\n";
}

```

Since you use the `*` after the hyphen, there can be any number of hyphens (including zero!) in the string. This is more handy for a variable amount of whitespace. Suppose you had the possibility of several spaces between the two parts of the name:

```
$_ = 'Bamm      bamm';
if (/Bamm *bamm/) {
    print "It matched!\n";
}
```

You could have another pattern to find a variable number of characters between the B and an m:

```
$_ = 'Bamm      bamm';
if (/B.*m/) {
    print "It matched!\n";
}
```

The longest part of the leftmost longest rule shows up here. The `.*` can match zero or more of any character except the newline, and so it does. In the process of matching, the `.*` matches the rest of the string all the way to the end of the string. We say that the quantifiers are *greedy* because they'll match as much as they can right away. Perl also has nongreedy matching, which you'll see in [Chapter 9](#).

NOTE

In reality, *perl* employs various optimization tricks to make matching faster, so a greedy `.*` might be slightly less greedy if the match operator knows it can do a little less work.

But the next part of the pattern can't match, because it is already at the end of the string. Perl then starts backtracking (or unmatching) so that it can satisfy the rest of the pattern. It only needs to back up one character for the rest of the pattern (just the `m`) to match. Thus, the pattern matches from the first B to the very last m because that's the longest match it can make.

This also means that a pattern with a `.*` at the start or end does more work than it needs to do. Since the `.*` can match zero characters, these patterns don't need it:

```
$_ = 'Bamm      bamm';
if (/B.*/) {
```

```

    print "It matched!\n";
}

if (/.*B/) {
    print "It matched!\n";
}

```

The `.` `*` can always match zero characters, so these patterns might as well match a single B:

```

$_ = 'Bamm      bamm';
if (/B/) {
    print "It matched!\n";
}

```

NOTE

The `Regexp::Debugger` module animates the process of matching so that you can see what the regex engine is doing. We show you how to install modules in [Chapter 11](#). We show more of this in the [“Watch regexes with Regexp::Debugger”](#) blog post.

Where the `*` matches zero or more times, the `+` quantifier matches one or more times. If there must be at least one space, use the `+`:

```

$_ = 'Bamm      bamm';
if (/Bamm +bamm/) {
    print "It matched!\n";
}

```

Those repetition operators match “or more” repetitions. What if you want to match an exact number? You can put that number in braces. Suppose you want to match exactly three bs. You can note that with `{3}`:

```

$_ = "yabbbbba dabbbba doo.";
if (/ab{3}a/) {
    print "It matched!\n";
}

```

That matches inside `dabbbba` because that's where exactly three bs are. This is a handy way to avoid manually counting the characters yourself.

The situation is a bit different if the quantifier is at the end of the pattern:

```
$_ = "yabbbbba dabbbba doo.";
if (/ab{3}/) {
    print "It matched!\n";
}
```

Now the pattern can match inside `yabbbbba` even though there are more than three bs. It doesn't limit the number of characters in the string, just the number it will match in the pattern.

If those aren't enough for you, there's the generalized quantifier where you get to choose the minimum and maximum times something can repeat. You put the minimum and maximum times to repeat in braces, such as `{2, 3}`. Going back to an earlier example, what if you wanted to allow for two to three bs inside the `abba`? You would specify the minimum and maximum times:

```
$_ = "yabbbbba dabbbba doo.";
if (/ab{2,3}a/) {
    print "It matched!\n";
}
```

This pattern will first try to match the `abbb` in `yabbbbba`, but after three bs there's another *b*. Perl has to move along to keep looking for a match, which it finds in `dabbbba` since it has at least two bs and at most three bs. That's the leftmost longest match.

You can specify a minimum number of repetitions with no maximum; just leave out the maximum. This one matches in `yabbbbba` because it has at least three bs and is the leftmost match:

```
$_ = "yabbbbba dabbbba doo.";
if (/ab{3,}a/) {
    print "It matched!\n";
}
```

Likewise, you can specify a maximum with no minimum by using 0 as the least number:

```
$_ = "yabbbba dabbba doo.";
if (/ab{0,5}a/) {
    print "It matched!\n";
}
```

Perl v5.34 removes the requirement to literally specify 0, in the same way that you can leave off the maximum. Now you can write the no-minimum case like {,n}:

```
use v5.34;
$_ = "yabbbba dabbba doo.";
if (/ab{,5}a/) { # will match
    print "It matched!\n";
}
```

Using 999 will match because there's a maximum of 999 bs but no minimum. Four or three bs satisfy that:

```
use v5.34;
$_ = "yabbbba dabbba doo.";
if (/ab{,999}a/) { # will match
    print "It matched!\n";
}
```

NOTE

Perl v5.34 allows you to add spaces inside the meta-curlies in a double-quoted context (which a pattern is one sort of), so {m,n} can also be { m,n }, {m , n}, and so on. This applies to quantifiers as well as things like \x{ }, \N{NAME}, and others.

Now you have more metacharacters to escape if you want the literal versions: ?, *, +, and {. Before v5.26 you could get away with some instances of unescaped literal {, but as Perl has expanded its regex features,

the `{` has been pressed into service to mean more things. An unescaped literal `}` is fine because it doesn't start anything and doesn't confuse Perl.

NOTE

Perl v5.28 temporarily relaxed the requirement to escape a literal `{` to give people more time to fix legacy code. Perl v5.30 re-added that requirement.

You can rewrite all of the quantifiers in terms of the general one, as shown in [Table 7-1](#).

Table 7-1. Regular expression quantifiers and their generalized forms

Number to match	Metacharacter	Generalized form
Optional	<code>?</code>	<code>{ 0, 1 }</code>
Zero or more	<code>*</code>	<code>{ 0, }</code>
One or more	<code>+</code>	<code>{ 1, }</code>
Minimum with no maximum		<code>{ 3, }</code>
Minimum with maximum		<code>{ 3, 5 }</code>
No minimum with maximum		<code>{ 0, 5 }</code> or <code>{ , 5 }</code> (v5.34)
Exactly		<code>{ 3 }</code>

Grouping in Patterns

You can use parentheses to group parts of a pattern. So, parentheses are also metacharacters.

Remember that a quantifier only applies to the immediately preceding item. The pattern `/fred+ /` matches strings like `freddddddddd` because the quantifier only applies to the `d`. If you want to match repetitions of the entire `fred`, you can group with parentheses, as in `/(fred)+ /`. The

quantifier applies to the entire group, so it matches strings like `fredfredfred`, which is more likely to be what you wanted.

The parentheses also give you a way to reuse part of the string directly in the match. You can use *back references* to refer to text that you matched in the parentheses, called a *capture group*. You denote a back reference as a backslash followed by a number, like `\1`, `\2`, and so on. The number denotes the capture group.

NOTE

You may also see “memories” or “capture buffers” in older documentation and earlier editions of this book, but the official name is “capture group.”

When you use the parentheses around the dot, you match any nonnewline character. You can match again whichever character you matched in those parentheses by using the back reference `\1`:

```
$_ = "abba";  
if (/(\.)\1/) { # matches 'bb'  
    print "It matched same character next to itself!\n";  
}
```

The `(.)\1` says that you have to match a character right next to itself. On the first try, the `(.)` matches an `a`, but when it looks at the back reference, which says the next thing it must match is `a`, that fails. Perl moves over one position in the string and starts the match over, using the `(.)` to match the next character, which is a `b`. The back reference `\1` now says that the next character in the pattern is `b`, which Perl can match.

The back reference doesn’t have to be right next to the capture group. The next pattern matches any four nonnewline characters after a literal `y`, and you use the `\1` back reference to denote that you want to match the same four characters after the `d`:

```

$_ = "yabba dabba doo";
if (/y(....) d\1/) {
    print "It matched the same after y and d!\n";
}

```

You can use multiple groups of parentheses, and each group gets its own back reference. Suppose you want to match a nonnewline character in a capture group, followed by another nonnewline character in a capture group. After those two groups, you use the back reference `\2` followed by the back reference `\1`. In effect, you're matching a palindrome such as `abba`:

```

$_ = "yabba dabba doo";
if (/y(.)()\2\1/) { # matches 'abba'
    print "It matched after the y!\n";
}

```

How do you know which group gets which number? Just count the order of the opening parentheses and ignore nesting:

```

$_ = "yabba dabba doo";
if (/y((.)(.)\3\2) d\1/) {
    print "It matched!\n";
}

```

You might be able to see this easier if you write out the regular expression to see the different parts (although this isn't a valid regular expression until we show you the `/x` flag in [Chapter 8](#)):

```

(          # first open parenthesis,  \1
  (.)      # second open parenthesis, \2
  (.)      # third open parenthesis,  \3
  \3
  \2
)

```

Perl 5.10 introduced a new way to denote back references. Instead of using the backslash and a number, you can use `\g{N}`, where `N` is the number of the back reference that you want to use.

Consider the problem where you want to use a back reference next to a part of the pattern that is a number. In this regular expression, you want to use `\1` to repeat the character you matched in the parentheses and follow that with the literal string `11`:

```
$_ = "aa11bb";
if (/(\.)\111/) {
    print "It matched!\n";
}
```

Perl has to guess what you mean there. Is that the back reference `\1`, `\11`, or `\111`? Perl will create as many back references as it needs, so it assumes that you meant the octal escape `\111`. Perl only reserves `\1` through `\9` for back references. After that, it does a bit of guessing to determine if it's a back reference or an octal escape.

By using `\g{1}`, you disambiguate the back reference and the literal parts of the pattern:

```
use v5.10;

$_ = "aa11bb";
if (/(\.)\g{1}11/) {
    print "It matched!\n";
}
```

You could leave the curly braces off the `\g{1}` and just use `\g1`, but in this case you need the braces. Instead of thinking about it, we recommend just using the braces all the time, at least until you're more sure of yourself.

You can also use negative numbers. Instead of specifying the absolute number of the capture group, you can specify a *relative back reference*. You can rewrite the last example to use `-1` as the number to do the same thing:

```
use v5.10;

$_ = "aa11bb";
if (/(\.)\g{-1}11/) {
```

```
    print "It matched!\n";  
}
```

If you add another capture group, you change the absolute numbering of all the back references. The relative back reference, however, just counts from its own position and refers to the group right before it no matter its absolute number, so it stays the same:

```
use v5.10;  
  
$_ = "xaallbb";  
if (/(.)(.)\g{-1}11/) {  
    print "It matched!\n";  
}
```

Alternation

The vertical bar (`|`), often called “or” in this usage, means that either the left side may match, or the right side. If the part of the pattern on the left of the bar fails, the part on the right gets a chance to match:

```
foreach ( qw(fred betty barney dino) ) {  
    if ( /fred|barney/ ) {  
        print "$_ matched\n";  
    }  
}
```

This outputs two names. One matches the left alternative and one matches the right:

```
fred matched  
barney matched
```

You can have more than one alternative:

```
foreach ( qw(fred betty barney dino) ) {  
    if ( /fred|barney|betty/ ) {  
        print "$_ matched\n";  
    }  
}
```

```
}  
}
```

This outputs three names:

```
fred matched  
betty matched  
barney matched
```

The alternation divides the pattern into sides, which might not be what you want. Suppose you want to match one of the Flintstones, but you don't care if it's Fred or Wilma. You might try this:

```
$_ = "Fred Rubble";  
if( /Fred|Wilma Flintstone/ ) { # unexpectedly matches  
    print "It matched!\n";  
}
```

It unexpectedly matches! The left alternative was simply Fred while the other alternative was Wilma Flintstone. Since Fred appears in \$_, it matches. If you want to limit the alternation, use parentheses to group it:

```
$_ = "Fred Rubble";  
if( /(Fred|Wilma) Flintstone/ ) { # doesn't match  
    print "It matched!\n";  
}
```

Perhaps your string has an annoying mix of tabs and spaces. Your alternation can have either: (|\t). To get one or more of those characters, apply the + quantifier:

```
$_ = "fred \t \t barney"; # could be tabs, spaces, or both  
if ( /fred( |\t)+barney/ ) {  
    print "It matched!\n";  
}
```

Applying the quantifier to the alternation as a group (created with the parentheses) is different than applying the quantifier to each item inside the alternation:

```
$_ = "fred \t \t barney"; # could be tabs, spaces, or both
if (/fred( +|\t+)barney/) { # all tabs or all spaces
    print "It matched!\n";
}
```

And note the difference without the parentheses. This pattern still matches even though there's no barney:

```
$_ = "fred \t \t wilma";
if (/fred |\tbarney/) {
    print "It matched!\n";
}
```

The pattern matches `fred` followed by a space, or it matches a tab followed by `barney`. It's everything on the left side or everything on the right side. If you want to limit the reach of the alternation, parentheses are the way to go.

Now consider a way to make your pattern case-insensitive. Maybe some people capitalize the second part of Bamm-Bamm's name, but some people don't. You can have an alternation that matches either case:

```
$_ = "Bamm-Bamm";
if (/Bamm-?(B|b)amm/) {
    print "The string has Bamm-Bamm\n";
}
```

Finally, consider an alternation to match any lowercase letter:

```
/(a|b|c|d|e|f|g|h|i|j|k|l|m|n|o|p|q|r|s|t|u|v|w|x|y|z)/
```

That's annoying, but we have a better way to do that. Keep reading!

Character Classes

Character classes are sets of characters that can match at a single location in the pattern. You put those characters in square braces, like `[abcxyz]`.

At that position in the pattern, it can match any one of those seven characters. It's a little like alternations but with individual characters.

For convenience, you can specify a range of characters with a hyphen (-), so that class may also be written as `[a-cw-z]`. That didn't save much typing, but it's more usual to make a character class like `[a-zA-Z]` to match any one letter out of that set of 52, or `[0-9]` to match a digit:

```
$_ = "The HAL-9000 requires authorization to continue.";
if (/HAL-[0-9]+)/ {
    print "The string mentions some model of HAL computer.\n";
}
```

If you wanted to match a literal hyphen, you either escape it or put the hyphen at the beginning or end:

<code>[-a]</code>	# hyphen or an a
<code>[a-]</code>	# hyphen or an a
<code>[a\-z]</code>	# hyphen or an a or a z
<code>[a-z]</code>	# lowercase letters from a to z

Inside the character class, a dot is a literal dot:

```
[5.32]      # matches a literal dot or a 5, 3, or 2
```

You may use the same character shortcuts in any double-quotish string to define a character, so the class `[\000-\177]` matches any seven-bit ASCII character. Inside those square braces, the `\n` and `\t` are still newlines and tabs. Remember that these patterns have their own mini-language, so these rules only apply inside regular expressions and not to other parts of Perl.

Now you have your second way to make a match case-insensitive. You can specify a position that can have the uppercase or lowercase version of a letter:

```
$_ = "Bamm-Bamm";
if (/Bamm-?[Bb]amm/) {
```

```
    print "The string has Bamm-Bamm\n";
}
```

Sometimes it's easier to specify the characters you want to leave out rather than the ones within the character class. A caret (^) at the start of the character class creates the complement of it:

```
[^def]      # anything not d, e, or f
[^n-z]      # not a lowercase letter from n to z
[^n\ -z]    # not an n, -, or z
```

This is handy when the list of characters that you don't want to match is shorter than the list of ones you do want.

Character Class Shortcuts

Some character classes are so common that Perl provides shortcuts, shown in [Table 7-2](#). For example, you could rewrite the earlier example for spaces or tabs to accept other sorts of whitespace between the names. The `\s` is a shortcut meaning “whitespace” (although it doesn't match every Unicode whitespace character: see `\p{Space}` later):

```
$_ = "fred \t \t barney";
if (/fred\s+barney/) { # whitespace
    print "It matched!\n";
}
```

That's not exactly what you had before, because whitespace includes more than just tabs or spaces. That might not matter to you. If you only wanted horizontal whitespace, you could use the `\h` shortcut introduced in v5.10:

```
$_ = "fred \t \t barney";
if (/fred\h+barney/) { # any whitespace
    print "It matched!\n";
}
```


NOTE

In Perl versions before v5.18, the `\s` didn't match the vertical tab: see the blog post “[Know your character classes under different semantics](#)” for more information.

You can abbreviate the character class for any digit as `\d`. Thus, you could write the pattern from the example about HAL as `/HAL-\d+/\` instead:

```
$_ = 'The HAL-9000 requires authorization to continue.';
if (/HAL-\d+/) {
    print "The string mentions some model of HAL computer.\n";
}
```

The shortcut `\w` is the so-called “word” character, although its idea of a word isn't like a normal word at all. The “word” was actually meant as an *identifier* character: the ones that you can use to name a Perl variable or subroutine.

The `\R` shortcut, introduced in Perl 5.10, matches any sort of linebreak, meaning that you don't have to think about which operating system you're using and what it thinks a linebreak is since `\R` will figure it out. This means you don't have to sweat the difference between `\r\n`, `\n`, and the other sorts of line endings that Unicode allows. It doesn't matter to you if there are DOS or Unix line endings. The `\R` isn't strictly a character class shortcut even though we note it here. It can match the two-character sequence `\r\n`, while real character classes match exactly one character.

You'll see more about these in [Chapter 8](#). The story is a bit more complicated than you've seen here.

Negating the Shortcuts

Sometimes you may want the opposite of one of these three shortcuts. That is, you may want `[^\d]`, `[^\w]`, or `[^\s]`, meaning a nondigit character, a nonword character, or a nonwhitespace character, respectively. That's easy

enough to accomplish by using their uppercase counterparts: `\D`, `\W`, and `\S`. These match any character that their counterpart would *not* match.

Table 7-2. ASCII character class shortcuts

Shortcut	Matches
<code>\d</code>	Decimal digits
<code>\D</code>	Not a decimal digit
<code>\s</code>	Whitespace
<code>\S</code>	Not whitespace
<code>\h</code>	Horizontal whitespace (v5.10 and later)
<code>\H</code>	Not horizontal whitespace (v5.10 and later)
<code>\v</code>	Vertical whitespace (v5.10 and later)
<code>\V</code>	Not vertical whitespace (v5.10 and later)
<code>\R</code>	Generalized line ending (v5.10 and later)
<code>\w</code>	“word”
<code>\W</code>	Not “word” characters
<code>\n</code>	Newline (not really a shortcut)
<code>\N</code>	Nonnewlines (stable in v5.18)

Any of these shortcuts will work either in place of a character class or inside the square brackets of a larger character class. For instance, `[\s\d]` will match whitespace and digits. Another compound character class is `[\d\D]`, which means any digit or any nondigit. That is to say, any character at all! This is a common way to match any character, including a newline.

Unicode Properties

Unicode characters know something about themselves; they aren't just sequences of bits. Every character knows not only what it is, but also what properties it has. Instead of matching on a particular character, you can match a type of character.

Each property has a name, which you can find in the [perluniprops documentation](#). To match a particular property, you put the name in `\p{PROPERTY}`. For instance, some characters are whitespace, corresponding to the property name `Space`. To match any sort of space, you use `\p{Space}`:

```
if (/\\p{Space}/) { # 25 different possible characters in v5.34
    print "The string has some whitespace.\n";
}
```

NOTE

The `\p{Space}` is slightly more expansive than `\s` because the property also matches NEXT LINE and NONBREAKING SPACE characters. It also matches LINE TABULATION (vertical tab), which `\s` did not match before v5.18.

If you want to match a digit, you use the `Digit` property, which matches the same characters as `\d`:

```
if (/\\p{Digit}/) { # 650 different possible characters in v5.34
    print "The string has a digit.\n";
}
```

Those are both much more expansive than the sets of characters you may have run into. Some properties are more specific, though. How about matching two hex digits, `[0-9A-Fa-f]`, next to each other:

```
if (/\\p{AHex}\\p{AHex}/) { # 22 different possible characters
    print "The string has a pair of hex digits.\n";
}
```

You can also match characters that *don't* have a particular Unicode property. Instead of a lowercase `p`, you use an uppercase one to negate the property:

```
if (/\P{Space}/) { # Not space (many many characters!)
    print "The string has one or more nonwhitespace characters.\n";
}
```

Perl uses the properties named by the Unicode Consortium (with a few exceptions) and adds some of its own for convenience. They are listed in [perluniprops](#).

Anchors

By default, if a pattern doesn't match at the start of the string, it can “float” down the string trying to match somewhere else. But there are a number of anchors that may be used to hold the pattern at a particular point in a string.

The `\A` anchor matches at the absolute beginning of a string, meaning that your pattern will not float down the string at all. This pattern looks for an `https` only at the start of the string:

```
if ( /\Ahttps?:/ ) {
    print "Found a URL\n";
}
```

The anchor is a *zero-width assertion*, meaning that it matches a condition at the current match position but doesn't match characters. In this case, the current match position has to be the beginning of the string. This keeps Perl from initially failing, moving over one character, and trying again.

If you want to anchor something to the end of the string, you use `\z`. This pattern matches `.png` only at the absolute end of the string:

```
if ( /\.png\z/ ) {
    print "Found a URL\n";
}
```

Why “absolute end of string”? We have to emphasize that nothing can come after the `\z`, because there is a bit of history here. There’s another end-of-string anchor, the `\Z`, which allows an optional newline after it. That makes it easy to match something at the end of a single line without worrying about the trailing newline:

```
while (<STDIN>) {  
    print if /\.png\Z/;  
}
```

If you had to think about the newline, you’d have to remove it before the match and put it back on for the output:

```
while (<STDIN>) {  
    chomp;  
    print "$_\n" if /\.png\z/;  
}
```

Sometimes you’ll want to use both of these anchors to ensure that the pattern matches an entire string. A common example is `/\A\s*\Z/`, which matches a blank line. But this “blank” line may include some whitespace characters, like tabs and spaces, which are invisible to us. Any line that matches that pattern looks just like any other one on paper, so this pattern treats all blank lines as equivalent. Without the anchors, it would match nonblank lines as well.

The `\A`, `\Z`, and `\z` are Perl 5 regular expression features, but not everyone uses them. In Perl 4, where many people picked up their programming habits, the beginning-of-string anchor was the caret (^) and the end-of-string anchor was `$`. Those still work in Perl 5, but they morphed into the beginning-of-line and end-of-line anchors, which are a bit different. We’ll show more about those in [Chapter 8](#).

Word Anchors

Anchors aren’t just at the ends of the string. The word-boundary anchor `\b` matches at either end of a word. So you can use `/\bfred\b/` to match the

word fred but not frederick or alfred or manfred mann. This is similar to the feature often called something like “match whole words only” in a word processor’s search command.

Alas, these aren’t words as we are likely to think of them; they’re those `\w`-type words made up of ordinary letters, digits, and underscores. The `\b` anchor matches at the start or end of a group of `\w` characters. This is subject to the rules that `\w` is following, as we showed you earlier in this chapter.

In [Figure 7-2](#), there’s a line under each “word,” and the arrows show the corresponding places where `\b` could match. There is always an even number of word boundaries in a given string, since there’s an end-of-word for every start-of-word.

The “words” are sequences of letters, digits, and underscores; that is, a word in this sense is what’s matched by `/\w+/.` There are five words in that sentence: `That`, `s`, `a`, `"word"`, and `boundary`. Notice that the quote marks around `word` don’t change the word boundaries; these words are made of `\w` characters.

Each arrow points to the beginning or the end of one of the gray underlines, since the word-boundary anchor `\b` matches only at the beginning or the end of a group of word characters.

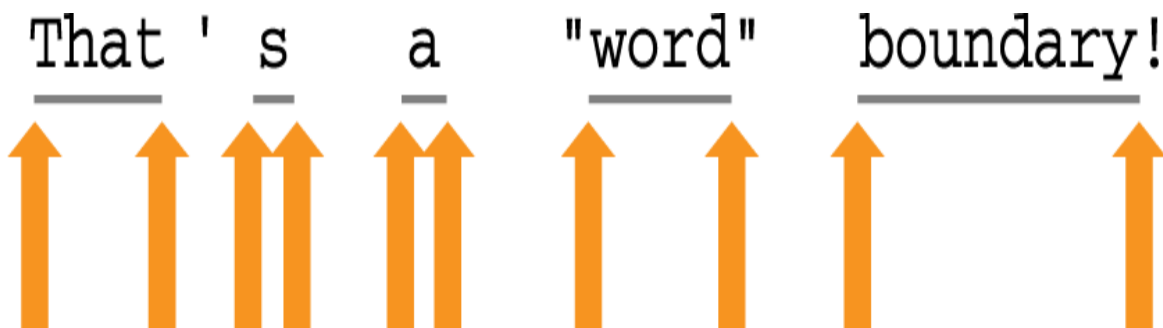


Figure 7-2. Word-boundary matches with `\b`

The word-boundary anchor is useful to ensure that you don’t accidentally find `cat` in `delicatessen`, `dog` in `boondoggle`, or `fish` in `selfishness`. Sometimes you’ll want just one word-boundary anchor, as

when using `/\bhunt/` to match words like `hunt` or `hunting` or `hunter` but not `shunt`, or when using `/stone\b/` to match words like `sandstone` or `flintstone` but not `capstones`.

The nonword-boundary anchor is `\B`; it matches at any point where `\b` would not match. So the pattern `/\bsearch\B/` will match `searches`, `searching`, and `searched` but not `search` or `researching`.

Perl v5.22 and v5.24 added fancier anchors, but you need more matching skills to see how they work. You'll see them in [Chapter 9](#) when we talk about the substitution operator.

Exercises

See [“Answers to Chapter 7 Exercises”](#) for answers to exercises.

Remember, it's normal to be surprised by some of the things that regular expressions do; that's one reason that the exercises in this chapter are even more important than the others. Expect the unexpected:

1. [10] Make a program that prints each line of its input that mentions `fred`. (It shouldn't do anything for other lines of input.) Does it match if your input string is `Fred`, `frederick`, or `Alfred`? Make a small text file with a few lines mentioning “fred flintstone” and his friends, then use that file as input to this program and the ones later in this section.
2. [6] Modify the previous program to allow `Fred` to match as well. Does it match now if your input string is `Fred`, `frederick`, or `Alfred`? (Add lines with these names to the text file.)
3. [6] Make a program that prints each line of its input that contains a period (.), ignoring other lines of input. Try it on the small text file from the previous exercise: does it notice `Mr. Slate`?
4. [8] Make a program that prints each line that has a word that is capitalized but not ALL capitalized. Does it match `Fred` but

neither fred nor FRED?

5. [8] Make a program that prints each line that has two of the same nonwhitespace characters next to each other. It should match lines that contain words such as Mississippi, Bamm-Bamm, or llama.
6. [8] Extra-credit exercise: write a program that prints out any input line that mentions *both* wilma and fred.

Chapter 8. Matching with Regular Expressions

In [Chapter 7](#), you visited the world of regular expressions. Now you'll see how that world fits into the world of Perl.

Matches with `m//`

You put patterns in pairs of forward slashes, like `/fred/`, but this is actually a shortcut for `m//`, the pattern match operator. As you saw with the `qw//` operator, you may choose any pair of delimiters to quote the contents. So you could write that same expression as `m(fred)`, `m<fred>`, `m{fred}`, or `m[fred]` using those paired delimiters, or as `m,fred,`, `m!fred!`, `m^fred^`, or many other ways using nonpaired delimiters.

NOTE

Nonpaired delimiters are the ones that don't have a different "left" and "right" variety; the same punctuation mark is used for both ends.

If you choose the forward slash as the delimiter, you may omit the initial `m`. Since Perl folks love to avoid typing extra characters, you'll see most pattern matches written using slashes, as in `/fred/`.

Of course, you should wisely choose a delimiter that doesn't appear in your pattern. If you wanted to make a pattern match the beginning of an ordinary web URL, you might start to write `/http:\\\\//` to match the initial `"http://"`. But that would be easier to read, write, maintain, and debug if you used a better choice of delimiter: `m%http://%`. It's common to use curly braces as the delimiter. If you use a programmer's text editor, it

probably has the ability to jump from an opening curly brace to the corresponding closing one, which can be handy in maintaining code.

If you're using paired delimiters, you shouldn't generally have to worry about using the delimiter inside the pattern, since that delimiter will usually be paired inside your pattern. That is, `m(fred(.*)barney)` and `m{\w{2,}}}` and `m[wilma[\n \t]+betty]` are all fine, even though the pattern contains the quoting character, since each “left” has a corresponding “right.” But the angle brackets (< and >) aren't regular expression metacharacters, so they may not be paired; if the pattern were `m{(\d+)\s*>=?\s*(\d+)}`, quoting it with angle brackets would mean having to backslash the greater-than sign so that it wouldn't prematurely end the pattern.

Match Modifiers

There are several modifier letters, sometimes called *flags*, which you can append as a group right after the ending delimiter. Some flags apply to the pattern and some change how the match operator behaves.

Case-Insensitive Matching with /i

To make a case-insensitive pattern match so that you can match FRED as easily as fred or Fred, use the /i modifier:

```
print "Would you like to play a game? ";
chomp($_ = <STDIN>);
if (/yes/i) { # case-insensitive match
    print "In that case, I recommend that you go bowling.\n";
}
```

Matching Any Character with /s

By default, the dot (.) doesn't match a newline, and this makes sense for most “look within a single line” patterns. If you might have newlines in your strings, and you want the dot to be able to match them, the /s

modifier will do the job. It changes every dot in the pattern to act like the character class `[\d\D]` does, which is to match any character, even if it is a newline. Of course, you have to have a string with newlines for this to make a difference:

```
$_ = "I saw Barney\ndown at the bowling alley\nwith Fred\nlast night.\n";
if (/Barney.*Fred/s) {
    print "That string mentions Fred after Barney!\n";
}
```

Without the `/s` modifier, that match would fail, since the two names aren't on the same line.

This sometimes leaves you with a problem, though. The `/s` modifier applies to every `.` in the pattern. What if you wanted to still match any character except a newline? You could use the character class `[^\n]`, but that's a bit much to type, so v5.12 added the shortcut `\N` to mean the complement of `\n`.

If you don't like the `/s` modifier to make every `.` match any character, you can make your own character class to match any character. Just include each side of a character class shortcut pair: `[\D\d]` or `[\S\s]`, for example. The combination of every nondigit and digit should be everything.

Adding Whitespace with `/x`

The `/x` modifier makes most whitespace inside the pattern insignificant. That way, you can spread out the pattern to more easily see what's going on:

```
/-?[0-9]+\.\?[0-9]*/      # what is this doing?
/ -? [0-9]+ \.\? [0-9]* /x  # a little better
```

Since the `/x` allows whitespace inside the pattern, Perl ignores literal space or tab characters within the pattern. You could use a backslashed space or `\t` (among many other ways) to match these, but it's more common to use

`\s` (or `\s*` or `\s+`) when you want to match whitespace. You can also escape a literal space (although that's hard to show in text), or use `\x{20}` or `\040`.

Remember that Perl considers comments a type of whitespace, so you can put comments into that pattern to tell other people what you are trying to do:

```
/
-?      # an optional minus sign
[0-9]+   # one or more digits before the decimal point
\.?     # an optional decimal point
[0-9]*   # some optional digits after the decimal point
/x
```

Since the pound sign indicates the start of a comment, you need to use the escaped character, `\#`, or the character class, `[#]`, if you need to match a literal pound sign:

```
/
[0-9]+   # one or more digits before the decimal point
[#]      # literal pound sign
/x
```

Also, be careful not to include the closing delimiter inside the comments, or it will prematurely terminate the pattern. This pattern ends before you think it does:

```
/
-?      # with / without - <--- OOPS!
[0-9]+   # one or more digits before the decimal point
\.?     # an optional decimal point
[0-9]*   # some optional digits after the decimal point
/x
```

When we started this section, we wrote “most whitespace” and then didn’t tell you the rest of the story. You can’t add insignificant whitespace inside a character class even with `/x`. Any characters inside the brackets, including

spaces and other whitespace, can match in the string. We're about to fix that, though.

Whitespace in character classes

Perl v5.26 added another way to add whitespace to a pattern. The `/xx` modifier does the same as `/x` but also allows you to add whitespace inside a character class without those whitespace characters becoming part of the class.

Consider this character class that matches six possible characters:

```
/ [abc123] /x  # matches a,b,c,1,2,3
```

That's not so hard to understand because it's short, but suppose those letters and numbers meant different things. There's a group of one sort of thing and there's a group of another sort of thing. You may want to separate those in the character class to show that, but it doesn't quite work because the space is now part of the character class:

```
/ [abc 123] /x  # matches a,b,c,1,2,3, or a space
```

To fix this, double up that `/x`:

```
use v5.26;
/ [abc 123] /xx  # matches a,b,c,1,2,3
/ [a-z 0-9] /xx  # matches lowercase letters or digits
```

Spread that over multiple lines if you like:

```
use v5.26;

/
  [
    abc
    123
  ]
/xx
```

But there's a limitation. While `/xx` lets you add that insignificant whitespace, it doesn't let you add comments. The comment in this example is really part of the character class. This means you'll also match characters that you didn't expect:

```
use v5.26;

/
  [
    abc  # not a comment!
    123
  ]
/xx
```

Note that the `/xx` allows spaces in ranges. Put a space in there and it's still a range:

```
use v5.26;
/[0 - 9]/xx    # still 0-9
```

Combining Option Modifiers

If you want to use more than one modifier on the same match, just put them both at the end (their order isn't significant):

```
if (/barney.*fred/is) { # both /i and /s
  print "That string mentions Fred after Barney!\n";
}
```

Or as a more expanded version with comments:

```
if (m{
  barney # the little guy
  .*    # anything in between
  fred  # the loud guy
}six) { # all three of /s and /i and /x
  print "That string mentions Fred after Barney!\n";
}
```

Note the shift to curly braces here for the delimiters, allowing programmer-style editors to easily bounce from the beginning to the end of the regular expression.

Choosing a Character Interpretation

Perl v5.14 adds some modifiers that let you tell Perl how to interpret the characters in a match for two important topics: case folding and character class shortcuts. Everything in this section applies to v5.14 or later.

The `/a` tells Perl to use the ASCII interpretation of character classes, the `/u` tells Perl to use Unicode, and the `/l` tells Perl to respect the locale. Without these modifiers, Perl does what it thinks is the right thing based on the situations described in the [perlre](#) documentation. You use these modifiers to tell Perl exactly what you want despite whatever else is going on in the program:

```
use v5.14;

/\w+/a    # A-Z, a-z, 0-9, _
/\w+/u    # any Unicode word character
/\w+/l    # The ASCII version, and word chars from the locale,
          # perhaps characters like Æ from Latin-9
```

Which one is right for you? We can't tell you, because we don't know what you're trying to do. Each of them might be right for you at different times. Of course, you can always create your own character classes to get exactly what you want if the shortcuts don't work for you.

Now on to a harder issue. Consider case folding, where you need to know which lowercase letter you should get from an uppercase letter. This is part of the “Unicode bug” in Perl, where the internal representation decides what answer you get. See the [perlunicode documentation](#) for the gory details.

If you want to match while ignoring case, Perl has to know how to produce lowercase characters. In ASCII, you know a *K*'s (0x4B) partner is a *k*

(0x6B). In ASCII, you also know that a *k*'s uppercase partner is *K* (0x4B), which seems sensible but actually is not.

NOTE

You may like to peruse [Unicode's case-folding rules](#). We'll show more in "Case Shifting".

In Unicode, things are not as simple, but it's still easy to deal with because the mapping is well defined. The Kelvin sign, *K* (U+212A), also has *k* (0x6B) as its lowercase partner. Even though *K* and *K* might look the same to you, they aren't to the computer. That is, lowercasing is not one-to-one. Once you get the lowercase *k*, you can't go back to its uppercase partner, because there is more than one uppercase character for it. Not only that, some characters, such as the ligature *ff* (U+FB00), have two characters as their lowercase equivalent—in this case, *ff*. The letter *ß* is *ss* in lowercase, but maybe you don't want to match that. A single */a* modifier affects the character class shortcuts, but if you have two */a* modifiers, it also tells Perl to use ASCII-only case folding:

```
/k/aii    # only matches the ASCII K or k, not Kelvin sign
/k/aia    # the /a's don't need to be next to each other
/ss/aii   # only matches ASCII ss, SS, sS, Ss, not ß
/ff/aii   # only matches ASCII ff, FF, fF, Ff, not ff
```

With locales it's not so simple. You have to know which locale you are using to know what a character is. If you have the ordinal value 0xBC, is that Latin-9's *Æ* or Latin-1's $\frac{1}{4}$ or something else in some other locale? You can't know how to lowercase it until you know what the locale thinks that value represents. We make the character with `chr()` to ensure that we get the right bit pattern regardless of the encoding issues:

```
$_ = <STDIN>;

my $OE = chr( 0xBC ); # get exactly what we intend

if (/$OE/i) {          # case-insensitive? Maybe not.
```



```

    print "Found $OE\n";
}

```

In this case, you might get different results depending on how Perl treats the string in `$_` and the string in the match operator. If your source code is in UTF-8 but your input is Latin-9, what happens? In Latin-9, the character *Œ* has ordinal value 0xBC and its lowercase partner *œ* has 0xBD. In Unicode, *Œ* is code point U+0152 and *œ* is code point U+0153. In Unicode, U+00BC is $\frac{1}{4}$ and doesn't have a lowercase version. If your input in `$_` is 0xBD and Perl treats that regular expression as UTF-8, you won't get the answer you expect. You can, however, add the `/l` modifier to force Perl to interpret the regular expression using the locale's rules:

```

use v5.14;

my $OE = chr( 0xBC ); # get exactly what we intend

$_ = <STDIN>;
if (/$OE/li) {        # that's better
    print "Found $OE\n";
}

```

If you always want to use Unicode semantics (which is the same as Latin-1) for this part, you can use the `/u` modifier:

```

use v5.14;

$_ = <STDIN>;
if (/$OE/ui) {        # now uses Unicode
    print "Found Œ\n";
}

```

If you think this is a big headache, you're right. No one likes this situation, but Perl does the best it can with the input and encodings it has to deal with. If only we could reset history and not make so many mistakes next time.

Beginning- and End-of-Line Anchors

What's the difference between the beginning-of-line and beginning-of-string? It comes down to the difference between how you think about lines and how the computer thinks about lines. When you match against the string in `$_`, Perl doesn't care what's in it. To Perl, it's just one big string, even if it looks like multiple lines to you because you have newlines in the string. Lines matter to humans because we spatially separate parts of the string:

```
$_ = 'This is a wilma line
barney is on another line
but this ends in fred
and a final dino line';
```

Suppose your task, however, is to find strings that have `fred` at the end of any line instead of just at the end of the entire string. In Perl 5, you can do that with the `$` anchor and the `/m` modifier to turn on multiline matching. This pattern matches because in the multiline string, `fred` is at the end of a line:

```
/fred$/m
```

The addition of the `/m` changes how the old Perl 4 anchor works. Now it matches `fred` anywhere as long as it's either followed by a newline anywhere in the string or is at the absolute end of the string.

The `/m` does the same for the `^` anchor, which then matches either at the absolute beginning of the string or anywhere after a newline. This pattern matches because in the multiline string, `barney` is at the beginning of a line:

```
/^barney/m
```

Without the `/m`, the `^` and `$` act just like `\A` and `\Z`. However, since someone might come along later and add a `/m` switch, changing your anchors to something you didn't intend, it's safer to use only the anchors that mean exactly what you want and nothing more. But as we said, many

programmers have habits they carried over from Perl 4, so you'll still see many `^` and `$` anchors that really should be `\A` and `\Z`. For the rest of the book, we'll use `\A` and `\Z` unless we specifically want multiline matching.

NOTE

The `re` module has a flags mode that allows you to set default flags for all match operators within its scope. Someone might make the `/m` flag the default.

Other Options

There are many other modifiers available. We'll cover those as we get to them, or you can read about them in the [perlop documentation](#) and in the descriptions of `m//` and the other regular expression operators that you'll see later in this chapter.

The Binding Operator `=~`

Matching against `$_` is merely the default; the *binding operator* (`=~`) tells Perl to match the pattern on the right against the string on the left, instead of matching against `$_`. For example:

```
my $some_other = "I dream of betty rubble.";
if ($some_other =~ /\brub/) {
    print "Aye, there's the rub.\n";
}
```

The first time you see it, the binding operator looks like some kind of assignment operator. But it's no such thing! It is simply saying, "This pattern match that would attach to `$_` by default—make it work with this string on the left instead." If there's no binding operator, the expression uses `$_` by default.

In the (somewhat unusual) next example, `$likes_perl` is set to a Boolean value according to what the user typed at the prompt. This is a

little on the quick-and-dirty side because you discard the line of input itself. This code reads the line of input, tests that string against the pattern, then discards the line of input. It doesn't use or change `$_` at all:

```
print "Do you like Perl? ";
my $likes_perl = (<STDIN> =~ /\byes\b/i);
... # Time passes...if ($likes_perl) {
    print "You said earlier that you like Perl, so...\n";
    ...
}
```

NOTE

Remember, Perl doesn't automatically store the line of input in `$_` unless the line-input operator (`<STDIN>`) is all alone in the conditional expression of a `while` loop.

Because the binding operator has fairly high precedence, the parentheses around the pattern test expression aren't required, so the following line does the same thing as the previous one—it stores the result of the test (and not the line of input) in the variable:

```
my $likes_perl = <STDIN> =~ /\byes\b/i;
```

The Match Variables

Parentheses normally trigger the regular expression engine's capturing features. The capture groups hold the part of the string matched by the part of the pattern inside parentheses. If there is more than one pair of parentheses, there will be more than one capture group. Each regular expression capture holds part of the original *string*, not part of the pattern. You could refer to these groups in your pattern using back references, but these groups also stick around after the match as the capture variables.

Since these variables hold strings, they are scalar variables; in Perl, they have names like `$1` and `$2`. There are as many of these variables as there are pairs of capturing parentheses in the pattern. As you'd expect, `$4` means

the string matched by the fourth set of parentheses. This is the same string that the back reference `\4` would refer to during the pattern match. But these aren't two different names for the same thing; `\4` refers back to the capture within the pattern while it is trying to match, while `$4` refers to the capture of an already *completed* pattern match. For more information on back references, see the [perlre documentation](#).

These match variables are a big part of the power of regular expressions because they let you pull out the parts of a string:

```
$_ = "Hello there, neighbor";
if (/s([a-zA-Z]+),/) {      # capture the word between space and
    print "the word was $1\n"; # the word was there
}
```

Or you could use more than one capture at once:

```
$_ = "Hello there, neighbor";
if (/(\S+) (\S+), (\S+)/) {
    print "words were $1 $2 $3\n";
}
```

That tells you that the words were `Hello there neighbor`. Notice that there's no comma in the output. Because the comma is outside the capture parentheses in the pattern, there is no comma in capture two. Using this technique, you can choose exactly what you want in the captures as well as what you want to leave out.

You could even have an empty match variable, if that part of the pattern might be empty. That is, a match variable may contain the empty string:

```
my $dino = "I fear that I'll be extinct after 1000 years.";
if ($dino =~ /([0-9]*) years/) {
    print "That said '$1' years.\n"; # 1000
}

$dino = "I fear that I'll be extinct after a few million years.";
if ($dino =~ /([0-9]*) years/) {
```

```

    print "That said '$1' years.\n"; # empty string
}

```

Remember that an empty string is different than an undefined one. If you have three or fewer sets of parentheses in the pattern, \$4 will be undef.

The Persistence of Captures

These capture variables generally stay around until the next *successful* pattern match. That is, an unsuccessful match leaves the previous capture values intact, but a successful one resets them all. This correctly implies that you shouldn't use these match variables unless the match succeeded; otherwise, you could be seeing a capture from some previous pattern. The following (bad) example is supposed to print a word matched from \$wilma. But if the match fails, it's using whatever leftover string happens to be found in \$1:

```

my $wilma = '123';
$wilma =~ /([0-9]+)/; # Succeeds, $1 is 123
$wilma =~ /([a-zA-Z]+)/; # BAD! Untested match result
print "Wilma's word was $1... or was it?\n"; # Still 123!

```

This is another reason a pattern match is almost always found in the conditional expression of an if or while:

```

if ($wilma =~ /([a-zA-Z]+)/) {
    print "Wilma's word was $1.\n";
} else {
    print "Wilma doesn't have a word.\n";
}

```

Since these captures don't stay around forever, you shouldn't use a match variable like \$1 more than a few lines after its pattern match. If your maintenance programmer adds a new regular expression between your regular expression and your use of \$1, you'll be getting the value of \$1 for the second match rather than the first. For this reason, if you need a capture

for more than a few lines, it's generally best to copy it into an ordinary variable. Doing this helps make the code more readable at the same time:

```
if ($wilma =~ /([a-zA-Z]+)/) {  
    my $wilma_word = $1;  
    ...  
}
```

Later, in **Chapter 9**, you'll see how to get the capture value *directly* into the variable at the same time as the pattern match happens, without having to use \$1 explicitly.

Captures in Alternations

Captures may show up in alternations, and the same rules apply to their numbering: count the order of the opening parentheses. However, only one of the branches can match. In the two captures here, which one has a value?

```
if ( $name =~ /(F\w+)|(P\w+)/ ) { # Fred or Pebbles?  
    print "1: $1\n2: $2\n";  
}
```

With warnings on, one of those capture variables will complain about an uninitialized value.

To complicate it further, add a third capture outside the alternation, making that capture \$4. Everything still works the same as what you already know:

```
/  
(  
    (F\w+) |      # $1  
    (P\d+)       # $2  
)  
\s+  
(\w+)          # $4  
/x
```

What happens when the alternation gets another branch? That new branch becomes \$4 and the last capture moves up to \$5:

```

/
(          # $1
  (F\w+) | # $2
  (P\d+) | # $3
  (Dino)   # $4, new capture
)
\s+
  (\w+)    # $5 now
/x

```

That's no good. What you probably want is to count that grouped alternation as a single thing, and whichever capture matches gets the same number. That way, you know the capture number (there's only one) and new branches don't disturb the rest of the pattern.

Perl v5.10 added the branch reset operator, `(?| . . .)`, to handle that:

```

/
(?|          # anything in here is $1
  (F\w+) |
  (P\d+) |
  (Dino)
)
\s+
  (\w+)      # $2
/x

```

In that contrived example, we can get the same thing by capturing the entire alternation because each branch captures everything:

```

/
(          # anything in here is $1
  F\w+ |
  P\d+ |
  Dino
)
\s+
  (\w+)    # $2
/x

```

The branch reset is handy when some of the branches match extra text that they don't capture:


```

/
(?:|          # anything in here is $1
  (Fr)ed    |
  (Peb)\d+  |
  (D)ino
)
\s+
(\w+)      # $2
/x

```

There's one more thing to note. Each branch can have a different number of captures, and the entire branch reset group will take up the same number of captures as the branch with the most. In this pattern, the third branch, (D) (.) no, has two captures, so the entire branch reset operator will have two captures. That's true even if the first branch, with only one capture, matches:

```

/
(?:|          # takes up $1 and $2 always
  (Fr)ed    |
  (Peb)\d+  |
  (D)(.)no  # has two captures!
)
\s+
(\w+)      # $3
/x

```

Noncapturing Parentheses

So far you've seen parentheses that capture parts of a matched string and store them in the capture variables, but what if you just want to use the parentheses to group things? Consider a regular expression where we want to make part of it optional but only capture another part of it. In this example, you want "bronto" to be optional, but to make it optional you have to group that sequence of characters with parentheses. Later in the pattern, you use an alternation to get either "steak" or "burger," and you want to know which one you found:

```

if (/(bronto)?saurus (steak|burger)/) {
    print "Fred wants a $2\n";
}

```

```
}
```

Even if “bronto” is not there, its part of the pattern goes into \$1. Perl just counts the order of the opening parentheses to decide what the capture variables will be. The part that you want to remember ends up in \$2. In more complicated patterns, this situation can get quite confusing.

Fortunately, Perl’s regular expressions have a way to use parentheses to group things but not trigger the capture groups, called *noncapturing parentheses*, and you write them with a special sequence. You add a question mark and a colon after the opening parenthesis, (?:), and that tells Perl you only want to use these parentheses for grouping.

You change your regular expression to use noncapturing parentheses around “bronto,” and the part that you want to remember now shows up in \$1:

```
if (/(?:bronto)?saurus (steak|burger)/) {  
    print "Fred wants a $1\n";  
}
```

Later, when you change your regular expression, perhaps to include a possible barbecue version of the brontosaurus burger, you can make the added “BBQ ” (with a space!) optional and noncapturing, so the part you want to remember still shows up in \$1. Otherwise, you’d potentially have to shift all of your capture variable names every time you add grouping parentheses to your regular expression:

```
if (/(?:bronto)?saurus (?:BBQ )?(steak|burger)/) {  
    print "Fred wants a $1\n";  
}
```

Perl’s regular expressions have several other special parentheses sequences that do fancy and complicated things, like look-ahead, look-behind, embed comments, or even run code right in the middle of a pattern. You’ll have to check out the [perlre documentation](#) for the details.

If you want to do a lot of grouping but no capturing, you can use the /n flag added in v5.22. It turns all parentheses into noncapturing groups:

```
if (/ (bronto)?saurus (BBQ )?(steak|burger)/n) {
  print "It matched\n"; # there is no $1 now
}
```

Named Captures

You can capture parts of the string with parentheses and then look in the number variables \$1, \$2, and so on to get the parts of the string that matched. Keeping track of those number variables and what should be in them can be confusing even for simple patterns. Consider this regular expression that tries to match the two names in \$names:

```
use v5.10;

my $names = 'Fred or Barney';
if ( $names =~ m/(\w+) and (\w+)/ ) { # won't match
  say "I saw $1 and $2";
}
```

You don't see the message from say, because the string has an or where you were expecting an and. Maybe you were supposed to have it both ways, so you change the regular expression to have an alternation to handle both and and or, adding another set of parentheses to group the alternation:

```
use v5.10;

my $names = 'Fred or Barney';
if ( $names =~ m/(\w+) (and|or) (\w+)/ ) { # matches now
  say "I saw $1 and $2";
}
```

Oops! You see a message this time, but it doesn't have the second name in it because you added another set of capture parentheses. The value in \$2 is from the alternation and the second name is now in \$3 (which we don't output):

```
I saw Fred and or
```

You could have used the noncapturing parentheses to get around this, but the real problem is that you have to remember which numbered parentheses belong to which data you are trying to capture. Imagine how much tougher this gets with many captures.

Instead of remembering numbers such as \$1, v5.10 or later lets you name the captures directly in the regular expression. It saves the text it matches in the hash named %+: the key is the label you used and the value is the part of the string that it matched. To label a match variable, you use (?<LABEL>PATTERN) where you replace LABEL with your own names. You label the first capture name1 and the second one name2, and look in \${name1} and \${name2} to find their values:

```
use v5.10;

my $names = 'Fred or Barney';
if ( $names =~ m/(?<name1>\w+) (?;and|or) (?<name2>\w+)/ ) {
    say "I saw ${name1} and ${name2}";
}
```

Now you see the right message:

```
I saw Fred and Barney
```

Once you label your captures, you can move them around and add additional capture groups without disturbing the order of the captures:

```
use v5.10;

my $names = 'Fred or Barney';
if ( $names =~ m/((?<name2>\w+) (and|or) (?<name1>\w+))/ ) {
    say "I saw ${name1} and ${name2}";
}
```

Now that you have a way to label matches, you also need a way to refer to them for back references. Previously, you used either \1 or \g{1} for this. With a labeled group, you can use the label in \g{label}:

```

use v5.10;

my $names = 'Fred Flintstone and Wilma Flintstone';

if ( $names =~ m/(?<last_name>\w+) and \w+ \g{last_name}/ ) {
    say "I saw ${last_name}";
}

```

You can do the same thing with another syntax. Instead of using `\g{label}`, you use `\k<label>`:

```

use v5.10;

my $names = 'Fred Flintstone and Wilma Flintstone';

if ( $names =~ m/(?<last_name>\w+) and \w+ \k<last_name>/ ) {
    say "I saw ${last_name}";
}

```

The `\k<label>` is essentially the same as `\g{label}`, but you can also use the `\g{ }` syntax for a relative back reference such as `\g{N}`. In patterns that have two or more labeled groups with the same label, `\k<label>` and `\g{label}` always refer to the leftmost group.

Perl also lets you use the Python syntax. The sequence `(?P<LABEL>...)` forms a capture and `(?P=LABEL)` refers to that capture:

```

use v5.10;

my $names = 'Fred Flintstone and Wilma Flintstone';

if ( $names =~ m/(?P<last_name>\w+) and \w+ (?P=last_name)/ ) {
    say "I saw ${last_name}";
}

```

The Automatic Match Variables

There are three more match variables that you get for free, whether the pattern has capture parentheses or not. That's the good news; the bad news is that these variables have weird names.

Now, Larry probably would have been happy enough to have called these by slightly less weird names, like perhaps `$gazoo` or `$ozmodiar`. But those are names that you just might want to use in your own code. To keep ordinary Perl programmers from having to memorize the names of *all* of Perl's special variables before choosing their first variable names in their first programs, Larry has given strange names to many of Perl's built-in variables—names that “break the rules.” In this case, the names are punctuation marks: `$&`, `$``, and `$'`. They're strange, ugly, and weird, but those are their names. The part of the string that actually matched the pattern is automatically stored in `$&`:

```
if ("Hello there, neighbor" =~ /\s(\w+),/) {  
    print "That actually matched '$&'.\n";  
}
```

That tells you that the part that matched was `" there, "` (with a space, a word, and a comma). Capture one, in `$1`, has just the five-letter word `there`, but `$&` has the entire matched section.

Whatever came before the matched section is in `$``, and whatever was after it is in `$'`. Another way to say that is that `$`` holds whatever the regular expression engine had to skip over before it found the match, and `$'` has the remainder of the string that the pattern never got to. If you glue these three strings together in order, you'll always get back the original string:

```
if ("Hello there, neighbor" =~ /\s(\w+),/) {  
    print "That was ($`)($&($')).\n";  
}
```

The message shows the string as `(Hello) (there,) (neighbor)`, showing the three automatic match variables in action. We'll show more of those variables in a moment.

Any or all of these three automatic match variables may be empty, of course, just like the numbered capture variables. And they have the same scope as the numbered match variables. Generally, that means they'll stay around until the next successful pattern match.

Now, we said earlier that these three are “free.” Well, freedom has its price. In this case, the price is that once you use any one of these automatic match variables anywhere in your program, every regular expression will run a little more slowly.

Granted, this isn’t a giant slowdown, but it’s enough of a worry that many Perl programmers will simply never use these automatic match variables. Instead, they’ll use a workaround. For example, if the only one you need is `$&`, just put parentheses around the whole pattern and use `$1` instead (you may need to renumber the pattern’s captures, of course).

If you are using v5.10 or later, though, you can have your cake and eat it too. The `/p` modifier lets you have the same sort of variables while only suffering the penalty for that particular regular expression. Instead of `$``, `$&`, or `$'`, you use `${^PREMATCH}`, `${^MATCH}`, or `${^POSTMATCH}`. The previous examples then turn into:

```
use v5.10;
if ("Hello there, neighbor" =~ /\s(\w+)/p) {
    print "That actually matched '${^MATCH}'.\n";
}

if ("Hello there, neighbor" =~ /\s(\w+)/p) {
    print "That was (${^PREMATCH}) (${^MATCH}) (${^POSTMATCH}).\n";
}
```

Those variable names look a bit odd since they have the braces around the name and start with `^`. As Perl evolves, it runs out of names it can use for special names. Starting with a `^` means it won’t clash with names that you might create (the `^` is an illegal character in a user-defined variable), but then it needs the braces to surround the entire variable name.

Match variables (both the automatic ones and the numbered ones) are most often used in substitutions, which you’ll see in [Chapter 9](#).

Precedence

With all of these metacharacters in regular expressions, you may feel that you can't keep track of the players without a scorecard. That's the precedence chart, which shows us which parts of the pattern “stick together” the most tightly. Unlike the precedence chart for operators, the regular expression precedence chart is simple, with only five levels. As a bonus, this section will review all of the metacharacters that Perl uses in patterns. **Table 8-1** shows the precedence, described here:

1. At the top of the precedence chart are the parentheses, (), used for grouping and capturing. Anything in parentheses will “stick together” more tightly than anything else.
2. The second level is the quantifiers. These are the repeat operators—star (*), plus (+), and question mark (?)—as well as the quantifiers made with curly braces, like {5,15}, {3,}, {,3} (new in v5.34), and {5}. These always stick to the item they follow.
3. The third level of the precedence chart holds anchors and sequence. The anchors are the \A, \Z, \z, ^, \$, \b, and \B anchors you've already seen. There's a \G anchor that we don't cover in this book. Sequence (putting one item after another) is actually an operator, even though it doesn't use a metacharacter. That means that letters in a word will stick together just as tightly as the anchors stick to the letters.
4. The next-to-lowest level of precedence is the vertical bar (|) of alternation. Since this is near the bottom of the chart, it effectively cuts the pattern into pieces. It's here because you want the letters in the words in /fred|barney/ to stick together more tightly than the alternation. If alternation were higher priority than sequence, that pattern would mean to match fre, followed by a choice of d or b, followed by arney. So, alternation is near the bottom of the chart, and the letters within the names stick together.

5. At the lowest level are the so-called *atoms* that make up the most basic pieces of the pattern. These are the individual characters, character classes, and back references.

Table 8-1. Regular expression precedence

Regular expression feature	Example
Parentheses (grouping or capturing)	(...), (?:...), (?<LABEL>...)
Quantifiers	a* a+ a? a{n,m}
Anchors and sequence	abc ^ \$ \A \b \B \z \Z
Alternation	a b c
Atoms	a [abc] \d \l \g{2}

Examples of Precedence

When you need to decipher a complex regular expression, you'll need to do as Perl does, and use the precedence chart to see what's really going on.

For example, `/\Afred|barney\z/` is probably not what the programmer intended. That's because the vertical bar of alternation is very low precedence; it cuts the pattern in two. That pattern matches either `fred` at the beginning of the string or `barney` at the end. It's much more likely that the programmer wanted `/\A(fred|barney)\z/`, which will match if the whole line has nothing but `fred` or nothing but `barney`. And what will `/(wilma|pebbles?)/` match? The question mark applies to the previous character, so that will match either `wilma` or `pebbles` or `pebble`, perhaps as part of a larger string (since there are no anchors).

The pattern `/\A(\w+)\s+(\w+)\z/` matches lines that have a “word,” some required whitespace, and another “word,” with nothing else before or after. That might be used to match lines like `fred flintstone`, for example. The parentheses around the words aren't needed for grouping, so

they may be intended to save those substrings into the regular expression captures.

When you're trying to understand a complex pattern, it may be helpful to add parentheses to clarify the precedence. That's OK, but remember that grouping parentheses are also automatically capturing parentheses; use the noncapturing parentheses if you just want to group things.

And There's More

Although we've covered all of the regular expression features that most people are likely to need for everyday programming, there are still even more features. A few are covered in *Intermediate Perl*, but also check the [perlre](#), [perlrequick](#), and [perlretut documentation](#) for more information about what patterns in Perl can do.

A Pattern Test Program

When in the course of Perl events it becomes necessary for a programmer to write a regular expression, it may be difficult to tell just what the pattern will do. It's normal to find that a pattern matches more than you expected, or less. Or it may match earlier in the string than you expected, or later, or not at all.

This program is useful to test out a pattern on some strings and see just what it matches, and where:

```
while (<>) {                # take one input line at a time
    chomp;
    if (/YOUR_PATTERN_GOES_HERE/) {
        print "Matched: |$`<$&>$'|\n";  # the special match vars
    } else {
        print "No match: |$_|\n";
    }
}
```

NOTE

If you aren't using the ebook (from which you can cut and paste this code), you can get this from the [Downloads section](#) of the book's companion website.

This pattern test program is written for programmers to use, not end users; you can tell because it doesn't have any prompts or usage information. It will take any number of input lines and check each one against the pattern that you'll put in place of the string saying `YOUR_PATTERN_GOES_HERE`. For each line that matches, it uses the three special match variables (`$``, `$&`, and `$'`) to make a picture of where the match happened. What you'll see is this: if the pattern is `/match/` and the input is `beforematchafter`, the output will say `|before<match>after|`, using angle brackets to show you just what part of the string was matched by your pattern. If your pattern matches something you didn't expect, you'll be able to see that right away.

Exercises

See “[Answers to Chapter 8 Exercises](#)” for answers to these exercises.

Several of these exercises ask you to use the test program from this chapter. You *could* manually type up this program, taking great care to get all of the odd punctuation marks correct, but you can also find it in the [Downloads section](#) of the book's companion website.

1. [8] Using the pattern test program, make a pattern to match the string `match`. Try the program with the input string `beforematchafter`. Does the output show the three parts of the match in the right order?
2. [7] Using the pattern test program, make a pattern that matches if any word (in the `\w` sense of word) ends with the letter `a`. Does it match `wilma` but not `barney`? Does it match `Mrs. Wilma Flintstone`? What about `wilma&fred`? Try it on the sample

text file from the Exercises in **Chapter 7** (and add these test strings if they weren't already in there).

3. [5] Modify the program from the previous exercise so that the word ending with the letter a is captured into \$1. Update the code to display that variable's contents in single quotes, something like `$1 contains 'Wilma'`.
4. [5] Modify the program from the previous exercise to use named captures instead of relying on \$1. Update the code to display that label name, something like `'word' contains 'Wilma'`.
5. [5] Extra-credit exercise: modify the program from the previous exercise so that immediately following the word ending in a it will also capture up to five characters (if there are that many characters, of course) in a separate capture variable. Update the code to display both capture variables. For example, if the input string says `I saw Wilma yesterday`, the up-to-five characters are “`yest`” (with the leading space). If the input is `I, Wilma!`, the extra capture should have just one character. Does your pattern still match just plain `wilma`?
6. [5] Write a new program (*not* the test program!) that prints out any input line ending with whitespace (other than just a newline). Put a marker character at the end of the output line so as to make the whitespace visible.

Chapter 9. Processing Text with Regular Expressions

You can use regular expressions to change text too. So far we've only shown you how to match a pattern, and now we'll show you how to use patterns to locate the parts of strings that you want to change.

Substitutions with `s///`

If you think of the `m//` pattern match as being like your word processor's "search" feature, the "search and replace" feature would be Perl's `s///` substitution operator. This simply replaces whatever part of a variable matches the pattern with a replacement string:

```
$_ = "He's out bowling with Barney tonight.";
s/Barney/Fred/; # Replace Barney with Fred
print "$_\n";
```

NOTE

Unlike `m//`, which can match against any string expression, `s///` is modifying data that must therefore be contained in what's known as an lvalue. This is nearly always a variable, but it could be anything you can use on the left side of an assignment operator.

If the match fails, nothing happens, and the variable is untouched:

```
# Continuing from previous; $_ has "He's out bowling with Fred
tonight."
s/Wilma/Betty/; # Replace Wilma with Betty (fails)
```

Of course, both the pattern and the replacement string could be more complex. Here, the replacement string uses the first capture variable, `$1`,

which is set by the pattern match:

```
s/with (\w+)/against $1's team/;
print "$_\n"; # says "He's out bowling against Fred's team
tonight."
```

Here are some other possible substitutions. These are here only as samples; in the real world, it would not be typical to do so many unrelated substitutions in a row:

```
$_ = "green scaly dinosaur";
s/(\w+) (\w+)/$2, $1/; # Now it's "scaly, green dinosaur"
s/\A/huge, /; # Now it's "huge, scaly, green dinosaur"
s/,.*een//; # Empty replacement: Now it's "huge
dinosaur"
s/green/red/; # Failed match: still "huge dinosaur"
s/\w+$/($`!)$&/; # Now it's "huge (huge !)dinosaur"
s/\s+(!\W+)/$1 /; # Now it's "huge (huge!) dinosaur"
s/huge/gigantic/; # Now it's "gigantic (huge!) dinosaur"
```

There's a useful Boolean value from `s///`; it's true if a substitution was successful, otherwise it's false:

```
$_ = "fred flintstone";
if (s/fred/wilma/) {
    print "Successfully replaced fred with wilma!\n";
}
```

Global Replacements with /g

As you may have noticed in a previous example, `s///` will make just one replacement, even if others are possible. Of course, that's just the default. The `/g` modifier tells `s///` to make all possible nonoverlapping replacements; that is, each new match starts looking just beyond the latest replacement:

```
$_ = "home, sweet home!";
s/home/cave/g;
print "$_\n"; # "cave, sweet cave!"
```

A fairly common use of a global replacement is to collapse whitespace; that is, to turn any arbitrary whitespace into a single space:

```
$_ = "Input  data\t may have    extra whitespace.";
s/\s+/ /g; # Now it says "Input data may have extra whitespace."
```

Once we show collapsing whitespace, everyone wants to know about stripping leading and trailing whitespace. That's easy enough, in two steps:

```
s/\A\s+//; # Replace leading whitespace with nothing
s/\s+\z//; # Replace trailing whitespace with nothing
```

We could do that in one step with an alternation and the `/g` modifier, but that turns out to be a bit slower, at least when we wrote this. The regular expression engine is always being tuned, but to learn more about that, you can get *Mastering Regular Expressions* by Jeffrey Friedl and find out what makes regular expressions fast (or slow):

```
s/\A\s+|\s+\z//g; # Strip leading, trailing whitespace
```

Different Delimiters

Just as you did with `m//` and `qw//`, you can change the delimiters for `s///`. But the substitution uses three delimiter characters, so things are a little different.

With ordinary (nonpaired) characters that don't have a left and right variety, just use three of them, as you did with the forward slash. Here, you use the octothorp (or pound sign) as the delimiter:

```
s#\Ahttps://#http://#;
```

But if you use paired characters, which have a left and right variety, you have to use two pairs: one to hold the pattern and one to hold the replacement string. In this case, the delimiters don't have to be the same kind around the string as they are around the pattern. In fact, the delimiters of the string could even be nonpaired. These are all the same:

```
s{fred}{barney};  
s[fred] (barney);  
s<fred>#barney#;
```

Substitution Modifiers

In addition to the `/g` modifier, you can use the `/i`, `/x`, `/m`, and `/s` modifiers that you saw in ordinary pattern matching (the order of modifiers isn't significant):

```
s#wilma#Wilma#gi; # replace every WiLmA or WILMA with Wilma  
s{__END__.*}{}s; # chop off the end marker and all following  
lines
```

The Binding Operator

Just as you saw with `m//`, we can choose a different target for `s///` by using the binding operator:

```
$file_name =~ s#\A.*/##s; # In $file_name, remove any Unix-style  
path
```

Nondestructive Substitutions

What if you want to have the original and the modified versions of a string at the same time? You could make a copy and work with that:

```
my $original = 'Fred ate 1 rib';  
my $copy = $original;  
$copy =~ s/\d+ ribs?/10 ribs/;
```

You could also write that as a single statement where you do the assignment and perform the substitution on the result:

```
(my $copy = $original) =~ s/\d+ ribs?/10 ribs/;
```

That can be a bit confusing because many people forget that the result of the assignment is just as good as a string, so it's really `$copy` that gets

changed. Perl 5.14 adds a `/r` modifier that changes how this works. Normally the result of a `s///` is the number of substitutions it made, but with the `/r`, it leaves the original string alone and returns a modified copy of it:

```
use v5.14;

my $copy = $original =~ s/\d+ ribs?/10 ribs/r;
```

That looks almost the same as the previous example, just without the parentheses. In this case, though, things happen in reverse order. You do the substitution first and the assignment second. [Chapter 2](#) (and the [perlop documentation](#)) has the precedence chart; the `=~` has higher precedence than the `=`.

Case Shifting

It often happens in a substitution that you'll want to make sure that a replacement word is properly capitalized (or not, as the case may be). That's easy to accomplish with Perl, by using some backslash escapes. The `\U` escape forces what follows to all uppercase:

```
$_ = "I saw Barney with Fred.";
s/(fred|barney)/\U$1/gi; # $_ is now "I saw BARNEY with FRED."
```

Remember all of our cautions in [“Choosing a Character Interpretation”](#)!

Similarly, the `\L` escape forces lowercase. Continuing from the previous code:

```
s/(fred|barney)/\L$1/gi; # $_ is now "I saw barney with fred."
```

By default, these affect the rest of the (replacement) string, or you can turn off case shifting with `\E`:

```
s/(\w+) with (\w+)/\U$2\E with $1/i; # $_ is now "I saw FRED
with barney."
```

When written in lowercase (`\l` and `\u`), they affect only the next character:

```
s/(fred|barney)/\u$1/ig; # $_ is now "I saw FRED with Barney."
```

You can even stack them up. Using `\u` with `\L` means “all lowercase, but capitalize the first letter”:

```
s/(fred|barney)/\u\L$1/ig; # $_ is now "I saw Fred with Barney."
```

As it happens, although we’re covering case shifting in relation to substitutions, these escape sequences are available in any double-quotish string:

```
print "Hello, \L\u$name\E, would you like to play a game?\n";
```

The `\L` and `\u` may appear together in either order. Larry realized that people would sometimes get those two backward, so he made Perl figure out that you want just the first letter capitalized and the rest lowercase.

Not all lowercasing is the same. Normally, you will probably lowercase things to normalize the string before you compare it:

```
my $input  = 'fRed';
my $string = 'FRED';
if ( "\L$input" eq "\L$string" ) {
    print "They are the same name\n";
}
```

However, not everything lowercases as you might expect, or there are equivalent forms. The `\l` is equivalent to `ss`, but:

```
use utf8;

my $input  = 'Steinerstraße';
my $string = 'STEINERSTRASSE';
if ( "\L$input" eq "\L$string" ) {          # doesn't work!
    print "They are the same name\n";
}
```

Those two don't match in Perl, even though they do match logically. Perl's lowercasing doesn't know the Unicode rules. If you have v5.16 or later and want proper Unicode case folding, you can use `\F` (for “foldcase”) escape:

```
use v5.16;

my $input  = 'Steinerstraße';
my $string = 'STEINERSTRASSE';
if ( "\F$input" eq "\F$string" ) {      # works
    print "They are the same name\n";
}
```

NOTE

The new case-folding feature does not help with strings such as `İstanbul` where the lowercase version of `I` is a dotted-i, but the combining dot also shows up, like `ı̇`. You can use the `Unicode::Casing` module for something more sophisticated.

These case-shifting operators are also available as the functions `lc`, `uc`, `fc`, `lcfirst`, and `ucfirst`:

```
my $start  = "Fred";
my $uncapp = lcfirst( $start );      # fred
my $uppered = uc( $uncapp );         # FRED
my $lowered = lc( $uppered );        # fred
my $capped  = ucfirst( $lowered );   # Fred
my $folded  = fc( $capped );         # fred
```

Metaquoting

There's another escape that's similar to case shifting. The `\Q` quotes any metacharacter in the string. Suppose you start with this pattern where you want to remove literal parentheses before a name:

```
if ( s/(((Fred/Fred/ ) {           # Does not compile!
    print "Removed parens\n";
}
```

You have to quote those characters to make them literal parentheses:

```
if ( s/\(\(\(\Fred/Fred/ ) {      # Compiles, but messy!
    print "Removed parens\n";
}
```

That can be annoying. All of those backslashes clutter the pattern. You can use `\Q`, which quotes everything after it. This makes the pattern a bit cleaner:

```
if ( s/\Q(((Fred/Fred/ ) {      # Less messy
    print "Removed parens\n";
}
```

If you want the quoting to apply to only part of the pattern, you can use the `\E`:

```
if ( s/\Q(((\E(Fred)/$1/ ) {    # Even less messy
    print "Cleansed $1\n";
}
```

This is useful if you want to interpolate a variable that you want to be literal characters. Since the interpolation happens, the `\Q` applies to the value in the variable:

```
if ( s/\Q$prefix\E(Fred)/$1/ ) {    # Compiles!
    print "Cleansed $1\n";
}
```

You can do the same thing ahead of time with the `quotemeta` function:

```
my $prefix = quotemeta( $input_pattern );
if ( s/$prefix(Fred)/$1/ ) {      # Compiles!
    print "Cleansed $1\n";
}
```

The split Operator

Another operator that uses regular expressions is `split`, which breaks up a string according to a pattern. This is useful for tab-separated data, or colon-separated, whitespace-separated, or *anything*-separated data, really. So long as you can specify the separator with a regular expression (and generally, it's a simple regular expression), you can use `split`. It looks like this:

```
my @fields = split /separator/, $string;
```

NOTE

Comma-separated values (CSV) files are a pain to do with `split`; you're better off getting the `Text::CSV_XS` module from CPAN.

The `split` drags the pattern through a string and returns a list of fields (substrings) that were separated by the separators. Whenever the pattern matches, that's the end of one field and the start of the next. So, anything that matches the pattern never shows up in the returned fields. Here's a typical `split` pattern, splitting on colons:

```
my @fields = split /:/, "abc:def:g:h"; # gives ("abc", "def",  
"g", "h")
```

You could even have an empty field, if there were two delimiters together:

```
my @fields = split /:/, "abc:def::g:h"; # gives ("abc", "def",  
"", "g", "h")
```

Here's a rule that seems odd at first, but it rarely causes problems—leading empty fields are always returned, but trailing empty fields are discarded:

```
my @fields = split /:/, ":::a:b:c::: "; # gives ("", "", "", "a",  
"b", "c")
```

If you want the trailing empty fields, give `split` a third argument of `-1`:

```
my @fields = split /:/, "::::a:b:c::::", -1; # gives
("", "", "", "a", "b", "c", "", "", "")
```

It's also common to `split` on whitespace, using `/\s+/` as the pattern. Under that pattern, all whitespace runs are equivalent to a single space:

```
my $some_input = "This  is a \t          test.\n";
my @args = split /\s+/, $some_input; # ("This", "is", "a",
"test.")
```

The default for `split` is to break up `$_` on whitespace:

```
my @fields = split; # like split /\s+/, $_;
```

This is almost the same as using `/\s+/` as the pattern, except that in this special case a leading empty field is suppressed—so, if the line starts with whitespace, you won't see an empty field at the start of the list. If you'd like to get the same behavior when splitting another string on whitespace, just use a single space in place of the pattern: `split ' ', $other_string`. Using a space instead of the pattern is a special kind of `split`.

Generally, the patterns you use for `split` are as simple as the ones you see here. But if the pattern becomes more complex, be sure to avoid using capturing parentheses in the pattern since these trigger the (usually) unwanted “separator retention mode” (see the [perlfunc documentation](#) for details). Use the noncapturing parentheses, `(?:)`, in `split` if you need to group things.

The join Function

The `join` function doesn't use patterns; it performs the opposite function of `split`: `split` breaks up a string into a number of pieces, and `join` glues together a bunch of pieces to make a single string. The `join` function looks like this:

```
my $result = join $glue, @pieces;
```

The first argument to `join` is the glue, which may be any string. The remaining arguments are a list of pieces. `join` puts the glue string between the pieces and returns the resulting string:

```
my $x = join ":", 4, 6, 8, 10, 12; # $x is "4:6:8:10:12"
```

In that example, you have five items, so there are only four colons. That is, there are four pieces of glue. The glue shows up only between the pieces, never before or after them. So, there will be one fewer piece of glue than the number of items in the list.

This means there may be no glue at all if the list doesn't have at least two elements:

```
my $y = join "foo", "bar";          # gives just "bar", since no foo
glue is needed
my @empty;                          # empty array
my $empty = join "baz", @empty;     # no items, so it's an empty
string
```

Using `$x` from earlier, you can break up a string and put it back together with a different delimiter:

```
my @values = split /:/, $x; # @values is (4, 6, 8, 10, 12)
my $z = join "-", @values;  # $z is "4-6-8-10-12"
```

Although `split` and `join` work well together, don't forget the first argument to `join` is always a string, not a pattern.

m// in List Context

When you use `split`, the pattern specifies the separator: the part that isn't the useful data. Sometimes it's easier to specify what you want to keep.

When a pattern match (`m/ /`) is used in a list context, the return value is a list of the capture variables created in the match, or an empty list if the match failed:

```
$_ = "Hello there, neighbor!";  
my ($first, $second, $third) = /(\S+) (\S+), (\S+)/;  
print "$second is my $third\n";
```

This makes it easy to give the match variables easy-to-use names, and these names may persist past the next pattern match. (Note also that, because there's no `=~` in that code, the pattern matches against `$_` by default.)

NOTE

Perl v5.26 adds the special `@{^CAPTURE}` array variable that holds all the capture variables. The first element is the same as `$&` (the entire match); the rest of the elements align with the capture buffer numbers.

The `/g` modifier that you first saw on `s/ /` also works with `m/ /`, which lets it match at more than one place in a string. In this case, a pattern with a pair of parentheses will return a capture from each time it matches:

```
my $text = "Fred dropped a 5 ton granite block on Mr. Slate";  
my @words = ($text =~ /([a-z]+)/ig);  
print "Result: @words\n";  
# Result: Fred dropped a ton granite block on Mr Slate
```

This is like using `split` “inside out”: instead of specifying what we want to remove, we specify what we want to keep.

In fact, if there is more than one pair of parentheses, each match may return more than one string. Let's say that we have a string that we want to read into a hash, something like this:

```
my $text = "Barney Rubble Fred Flintstone Wilma Flintstone";  
my %last_name = ($text =~ /(\w+)\s+(\w+)/g);
```


Each time the pattern matches, it returns a pair of captures. Those pairs of values then become the key-value pairs in the newly created hash.

More Powerful Regular Expressions

After already reading three (almost!) chapters about regular expressions, you know that they're a powerful feature in the core of Perl. But there are even more features that the Perl developers have added; you'll see some of the most important ones in this section. At the same time, you'll see a little more about the internal operation of the regular expression engine.

Nongreedy Quantifiers

So far Perl's quantifiers have been greedy. They match as much text as they can using the leftmost longest rule. Sometimes this means that you match too much.

Consider this example where you want to replace a name between tags with an all uppercase version:

```
my $text = '<b>Fred</b> and <b>Barney</b>';
$text =~ s/<b>(.*?)</b>|<b>\U$1\E</b>|g;
print "$text\n";
```

It doesn't work:

```
<b>FRED</B> AND <B>BARNEY</b>
```

What happened? You tried to do a global match and expected two matches? How many actually matched?

```
my $text = '<b>Fred</b> and <b>Barney</b>';
my $match_count = $text =~ s/<b>(.*?)</b>|\U$1|g;
print "$match_count: $text\n";
```

You see that there was only one match:

```
1: FRED</B> AND <B>BARNEY
```

Since the `. *` is greedy, it matched everything from the first `` to the *last* ``. You wanted it to match from a `` to the *next* ``. This is one of the problems with parsing HTML with regular expressions.

NOTE

Most Perlers will tell you that you can't parse HTML with regexes, but that's more about your skill and attention to detail than Perl's ability. Tom Christiansen shows that you can in an [answer on StackOverflow](#).

You don't want the `. *` to match the longest portion it can. You want it to match just enough. If you add a `?` after any quantifier, that quantifier stops matching when it first finds the part after the quantifier:

```
my $text = '<b>Fred</b> and <b>Barney</b>';
my $match_count = $text =~ s|<b>(.*?)</b>|\U$1|g; # nongreedy
print "$match_count: $text\n";
```

Now it makes two matches and only the names are capitalized:

```
2: FRED and BARNEY
```

Instead of matching to the end of the string and backtracking until it finds a way to match the rest of the pattern, the regex keeps checking that it hasn't run into the next part of the pattern (see [Table 9-1](#)).

Table 9-1. Regular expression quantifiers with the nongreedy modifier

Metacharacter	Number to match
??	Least of zero or one match
*?	Zero or more, as few as possible
+?	One or more, as few as possible
{3, }?	At least three, but as few as possible
{3, 5}?	At least three, as many as five, but as few as possible

Fancier Word Boundaries

The `\b` matches between a “word” character and a non-“word” character. As you saw in [Chapter 7](#), Perl’s idea of a word is a bit different than ours. Suppose that you wanted to capitalize the first letter of each word in a string. You might think that you could substitute anything right after a word boundary:

```
my $string = "This doesn't capitalize correctly.";
$string =~ s/\b(\w)/\U$1/g;
print "$string\n";
```

By Perl’s definition, that apostrophe is a word boundary even though it’s in the middle of a word (well, a contraction of two words, but still):

```
This Doesn'T Capitalize Correctly.
```

NOTE

Unicode specifies levels of regular expression compliance in [Unicode Technical Report #18](#), which includes sophisticated boundary assertions. Perl aims to be the most Unicode-compliant language out there.

Perl v5.22 added a new sort of word boundary based on the Unicode definition. That definition looks farther around the position to make a better guess about where a word might start or end. The new boundary syntax builds on `\b` by adding curly braces to denote the sort of boundary:

```
use v5.22;

my $string = "this doesn't capitalize correctly.";
$string =~ s/\b{wb}(\w)/\U$1/g;
print "$string\n";
```

The `\b{wb}` is smart enough to recognize that the `t` after the apostrophe is not the start of a new word:

```
This Doesn't Capitalize Correctly.
```

The rules it uses are a bit convoluted and they aren't perfect, but they do better than the old `\b`.

There's also a new sentence boundary in v5.22. The `\b{sb}` uses a set of rules to guess if punctuation is at the end of a sentence or is internal punctuation, such as in "Mr. Flintstone."

That's not enough, though. Perl v5.24 adds a line boundary, which indicates a good place to break text so that you don't wrap a line in the middle of a word, at inappropriate punctuation, or at a nonbreaking space. The `\b{lb}` knows where to insert the newlines:

```
$string =~ s/({50,75}\b{lb})/$1\n/g;
```

Like the other fancy word boundaries, this one guesses based on heuristics. In some cases it might not break where you think it should.

Matching Multiple-Line Text

Classic regular expressions were used to match just single lines of text. But since Perl can work with strings of any length, Perl's patterns can match multiple lines of text as easily as single lines. Of course, you have to include an expression that holds more than one line of text. Here's a string that's four lines long:

```
$_ = "I'm much better\nthan Barney is\nat bowling,\nWilma.\n";
```

Now, the anchors `^` and `$` are normally anchors for the start and end of the whole string ([Chapter 8](#)). But the `/m` regular expression option lets them match at internal newlines as well (think `m` for multiple lines). This makes them anchors for the start and end of each *line* rather than the whole string. So this pattern can match:

```
print "Found 'wilma' at start of line\n" if /^wilma\b/im;
```

Similarly, you could do a substitution on each line in a multiline string. Here, we read an entire file into one variable, then add the file's name as a prefix at the start of each line:

```
open FILE, $filename
  or die "Can't open '$filename': $!";
my $lines = join '', <FILE>;
$lines =~ s/^/$filename: /gm;
```

Updating Many Files

The most common way of programmatically updating a text file is by writing an entirely new file that looks similar to the old one but making whatever changes we need as we go along. As you'll see, this technique

gives nearly the same result as updating the file itself, but it has some beneficial side effects as well.

In this example, suppose you have hundreds of files with a similar format. One of them is *fred03.dat*, and it's full of lines like these:

```
Program name: granite
Author: Gilbert Bates
Company: RockSoft
Department: R&D
Phone: +1 503 555-0095
Date: Tues March 9, 2004
Version: 2.1
Size: 21k
Status: Final beta
```

You need to fix this file so that it has some different information. Here's roughly what this one should look like when you're done:

```
Program name: granite
Author: Randal L. Schwartz
Company: RockSoft
Department: R&D
Date: June 12, 2008 6:38 pm
Version: 2.1
Size: 21k
Status: Final beta
```

In short, you need to make three changes. The name of the `Author` should be changed; the `Date` should be updated to today's date; and the `Phone` should be removed completely. And you have to make these changes in hundreds of similar files as well.

Perl supports a way of in-place editing of files with a little extra help from the diamond operator (`<>`). Here's a program to do what you want, although it may not be obvious how it works at first. This program's only new feature is the special variable `$^I`; ignore that for now, and we'll come back to it:

```
#!/usr/bin/perl -w

use strict;
```

```

chomp(my $date = `date`);
$^I = ".bak";

while (<>) {
    s/\AAuthor:.*\/Author: Randal L. Schwartz/;
    s/\APhone:.*\n//;
    s/\ADate:.*\/Date: $date/;
    print;
}

```

Since you need today's date, the program starts by using the system *date* command. A better way to get the date (in a slightly different format) would almost surely be to use Perl's own `localtime` function in a scalar context:

```

my $date = localtime;

```

The next line sets `$^I`, but keep ignoring that for the moment.

The list of files for the diamond operator here is coming from the command line. The main loop reads, updates, and prints one line at a time. With what you know so far, that means that you'll dump all of the files' newly modified contents to your terminal, scrolling furiously past your eyes, without the files being changed at all. But stick with us. Note that the second substitution can replace the entire line containing the phone number with an empty string—leaving not even a newline—so when that's printed, nothing comes out, and it's as if the `Phone` never existed. Most input lines won't match any of the three patterns, and those will be unchanged in the output.

So this result is close to what you want, except that we haven't shown you how the updated information gets back out onto the disk. The answer is in the variable `$^I`. By default it's `undef`, and everything is normal. But when it's set to some string, it makes the diamond operator (`<>`) even more magical than usual.

You already know about much of the diamond's magic—it will automatically open and close a series of files for you, or read from the

standard-input stream if there aren't any filenames given. But when there's a string in `$^I`, that string is used as a backup filename's extension. Let's see that in action.

Let's say it's time for the diamond to open our file *fred03.dat*. It opens it like before, but now it renames it, calling it *fred03.dat.bak*. You've still got the same file open, but now it has a different name on the disk. Next, the diamond creates a new file and gives it the name *fred03.dat*. That's OK; you weren't using that name anymore. And now the diamond selects the new file as the default for output so that anything that we print will go into that file. Now the `while` loop will read a line from the old file, update that, and print it out to the new file. This program can update thousands of files in a few seconds on a typical machine. Pretty powerful, huh?

NOTE

The diamond also tries to duplicate the original file's permission and ownership settings as much as possible. See the documentation for your particular system for details.

Once the program has finished, what does the user see? The user says, "Ah, I see what happened! Perl edited my file *fred03.dat*, making the changes I needed, and saved me a copy of the original in the backup file *fred03.dat.bak* just to be helpful!" But you now know the truth: Perl didn't really edit any file. It made a modified copy, said "Abracadabra!", and switched the files around while you were watching sparks come out of the magic wand. Tricky.

Some folks use a tilde (~) as the value for `$^I`, since that resembles what *emacs* does for backup files. Another possible value for `$^I` is the empty string. This enables in-place editing, but doesn't save the original data in a backup file. Since a small typo in your pattern could wipe out all of the old data though, using the empty string is recommended only if you want to find out how good your backup tapes are. It's easy enough to delete the backup files when you're done. And when something goes wrong and you need to rename the backup files to their original names, you'll be glad that

you know how to use Perl to do that (we'll show you an example in ["Renaming Files"](#)).

In-Place Editing from the Command Line

A program like the example from the previous section is fairly easy to write. But Larry decided it wasn't easy enough.

Imagine that you need to update hundreds of files that have the misspelling `Randall` instead of the one-l name `Randal`. You could write a program like the one in the previous section. Or you could do it all with a one-line program, right on the command line:

```
$ perl -p -i.bak -w -e 's/Randall/Randal/g' fred*.dat
```

Perl has a whole slew of command-line options you can use to build a complete program in a few keystrokes. Let's see what these few do (and see [perlrun](#) for the rest).

Starting the command with *perl* does something like putting `#!/usr/bin/perl` at the top of a file: it says to use the program *perl* to process what follows.

The `-p` option tells Perl to write a program for you. It's not much of a program, though; it looks something like this:

```
while (<>) {  
    print;  
}
```

If you want even less, you could use `-n` instead; that leaves out the automatic `print` statement, so you can print only what you wish. (Fans of *awk* will recognize `-p` and `-n`.) Again, it's not much of a program, but it's pretty good for the price of a few keystrokes.

The next option is `-i.bak`, which you might have guessed sets `$^I` to `".bak"` before the program starts. If you don't want a backup file, you can

use `-i` alone, with no extension. If you don't want a spare parachute, you can leave the airplane with just one.

You've seen `-w` before—it turns on warnings.

The `-e` option says “executable code follows.” That means that the `s/Randall/Randal/g` string is treated as Perl code. Since you've already got a `while` loop (from the `-p` option), this code is put inside the loop, before the `print`. For technical reasons, the last semicolon in the `-e` code is optional. But if you have more than one `-e`, and thus more than one chunk of code, you can safely omit only the semicolon at the end of the last one.

The last command-line parameter is `fred*.dat`, which says that `@ARGV` should hold the list of filenames that match that filename pattern. Put the pieces all together, and it's as if you had written a program like this, and put it to work on all of those `fred*.dat` files:

```
#!/usr/bin/perl -w

$^I = ".bak";

while (<>) {
    s/Randall/Randal/g;
    print;
}
```

Compare this program to the one you used in the previous section. It's pretty similar. These command-line options are pretty handy, aren't they?

Exercises

See “[Answers to Chapter 9 Exercises](#)” for answers to these exercises:

1. [7] Make a pattern that will match three consecutive copies of whatever is currently contained in `$what`. That is, if `$what` is `fred`, your pattern should match `fredfredfred`. If `$what` is `fred|barney`, your pattern should match `fredfredbarney`

or barneyfredfred or barneybarneybarney or many other variations. (Hint: you should set `$what` at the top of the pattern test program with a statement like `my $what = 'fred|barney';`.)

2. [12] Write a program that makes a modified copy of a text file. In the copy, every string Fred (case-insensitive) should be replaced with Larry. (So Manfred Mann should become ManLarry Mann.) The input filename should be given on the command line (don't ask the user!), and the output filename should be the corresponding filename ending with `.out`.
3. [8] Modify the previous program to change every Fred to Wilma and every Wilma to Fred. Now, input like `fred&wilma` should look like `Wilma&Fred` in the output.
4. [10] Extra-credit exercise: write a program to add a copyright line to all of your exercise answers so far, by placing a line like:

```
## Copyright (C) 20XX by Yours Truly
```

in the file immediately after the “shebang” line. You should edit the files “in place,” keeping a backup. Presume that the program will be invoked with the filenames to edit already on the command line.

5. [15] Extra extra-credit exercise: modify the previous program so that it doesn't edit the files that already contain the copyright line. As a hint on that, you might need to know that the name of the file being read by the diamond operator is in `$ARGV`.

Chapter 10. More Control Structures

In this chapter, you'll see some alternative ways to write Perl code. For the most part, these techniques don't make the language more powerful, but they do make it easier or more convenient to get the job done. You don't have to use these techniques in your own code, but don't be tempted to skip this chapter—you're certain to see these control structures in other people's code sooner or later (in fact, you're absolutely certain to see these things in use by the time you finish reading this book).

The **unless** Control Structure

In an `if` control structure, the block of code is executed only when the conditional expression is true. If you want to execute a block of code only when the conditional is false, change `if` to `unless`:

```
unless ($fred =~ /\A[A-Z_]\w*\z/i) {  
    print "The value of \$fred doesn't look like a Perl identifier  
    name.\n";  
}
```

Using `unless` says to run the block of code *unless* this condition is true. It's just like using an `if` test with the opposite condition. Another way to say it is that it's like having the `else` clause on its own. That is, whenever you see an `unless` that you don't understand, you can rewrite it (either in your head or in reality) as an `if` test:

```
if ($fred =~ /\A[A-Z_]\w*\z/i) {  
    # Do nothing  
} else {  
    print "The value of \$fred doesn't look like a Perl identifier
```

```
name.\n";  
}
```

It's no more or less efficient, and it should compile to the same internal bytecodes. Or, another way to rewrite it would be to negate the conditional expression by using the negation operator (!):

```
if ( ! ($fred =~ /\A[A-Z_]\w*\z/i) ) {  
    print "The value of \$_fred doesn't look like a Perl identifier  
name.\n";  
}
```

Generally, you should pick the way of writing code that makes the most sense to you, since that will probably make the most sense to your maintenance programmer. If it makes the most sense to write `if` with a negation, do that. More often, however, you'll probably find it natural to use `unless`.

The else Clause with unless

You could even have an `else` clause with an `unless`. While this syntax is supported, it's potentially confusing:

```
unless ($mon =~ /\AFeb/) {  
    print "This month has at least thirty days.\n";  
} else {  
    print "Do you see what's going on here?\n";  
}
```

Some people may wish to use this, especially when the first clause is very short (perhaps only one line) and the second is several lines of code. But you could make this one a negated `if`, or maybe simply swap the clauses to make a normal `if`:

```
if ($mon =~ /\AFeb/) {  
    print "Do you see what's going on here?\n";  
} else {  
    print "This month has at least thirty days.\n";  
}
```

It's important to remember that you're always writing code for two readers: the computer that will run the code and the human being who has to keep the code working. If the human can't understand what you've written, pretty soon the computer won't be doing the right thing either.

The until Control Structure

Sometimes you want to reverse the condition of a `while` loop. To do that, just use `until`:

```
until ($j > $i) {  
    $j *= 2;  
}
```

This loop runs until the conditional expression returns true. But it's really just a `while` loop in disguise, except that this one repeats as long as the conditional is false rather than true. The conditional expression is evaluated before the first iteration, so this is still a zero-or-more-times loop, just like the `while` loop. As with `if` and `unless`, you could rewrite any `until` loop to become a `while` loop by negating the condition. But generally, you'll find it simple and natural to use `until` from time to time.

Statement Modifiers

In order to have a more compact notation, a statement may be followed by a modifier that controls it. For example, the `if` modifier works in a way analogous to an `if` block:

```
print "$n is a negative number.\n" if $n < 0;
```

That gives exactly the same result as if you had used this code, except that you saved some typing by leaving out the parentheses and curly braces:

```
if ($n < 0) {  
    print "$n is a negative number.\n";  
}
```

```
}
```

As we've said, Perl folks generally like to avoid typing. And the shorter form reads like in English: print this message if `$n` is less than zero.

Notice that the conditional expression is still evaluated first, even though it's written at the end. This is backward from the usual left-to-right ordering; in understanding Perl code, you have to do as Perl's internal compiler does, and read to the end of the statement before you can tell what it's really doing.

There are other modifiers as well:

```
&error("Invalid input") unless &valid($input);  
$i *= 2 until $i > $j;  
print " ", ($n += 2) while $n < 10;  
&greet($_) foreach @person;
```

These all work just as (we hope) you would expect. That is, each one could be rewritten in a similar way to rewriting the `if` modifier example earlier. Here is one:

```
while ($n < 10) {  
    print " ", ($n += 2);  
}
```

The expression in parentheses inside the `print` argument list is noteworthy because it adds two to `$n`, storing the result back in `$n`. Then it returns that new value, which will be printed.

These shorter forms read almost like a natural language: call the `&greet` subroutine for each `@person` in the list. Double `$i` until it's larger than `$j`. One of the common uses of these modifiers is in a statement like this one:

```
print "fred is '$fred', barney is '$barney'\n" if $I_am_curious;
```

By writing the code “in reverse” like this, you can put the important part of the statement at the beginning. The point of that statement is to monitor some variables; the point is not to check whether you’re curious. Of course, we made up the name `$I_am_curious`; it’s not a built-in Perl variable. Generally, folks who use this technique will either call their variable `$TRACING` or will use a constant declared with the `constant` pragma. Some people prefer to write the whole statement on one line, perhaps with some tab characters before the `if`, to move it over toward the right margin as you saw in the previous example, while others put the `if` modifier indented on a new line:

```
print "fred is '$fred', barney is '$barney'\n"
    if $I_am_curious;
```

Although you can rewrite any of these expressions with modifiers as a block (the “old-fashioned” way), the converse isn’t necessarily true. Perl allows only a single expression on either side of the modifier. So you can’t write something `if` something `while` something `until` something `unless` something `foreach` something, which would just be too confusing. And you can’t put multiple statements on the left of the modifier. If you need more than just a simple expression on either side, just write the code the old-fashioned way, with the parentheses and curly braces.

As we mentioned in relation to the `if` modifier, the control expression (on the right) is always evaluated first, just as it would be in the old-fashioned form.

With the `foreach` modifier, there’s no way to choose a different control variable—it’s always `$_`. Usually, that’s not a problem, but if you want to use a different variable, you’ll need to rewrite it as a traditional `foreach` loop.

The Naked Block Control Structure

The so-called “naked” block is one without a keyword or condition. That is, suppose you start with a `while` loop, which looks something like this:

```
while (condition) {  
    body;  
    body;  
    body;  
}
```

Now, take away the `while` keyword and the conditional expression, and you’ll have a naked block:

```
{  
    body;  
    body;  
    body;  
}
```

The naked block is like a `while` or `foreach` loop, except that it doesn’t loop; it just executes the body of the loop once, and it’s done. It’s an un-loop!

Later, you’ll see that there are other uses for the naked block, but one of its features is that it provides a scope for temporary lexical variables:

```
{  
    print "Please enter a number: ";  
    chomp(my $n = <STDIN>);  
    my $root = sqrt $n; # calculate the square root  
    print "The square root of $n is $root.\n";  
}
```

In this block, `$n` and `$root` are temporary variables scoped to the block. As a general guideline, all variables should be declared in the smallest scope available. If you need a variable for just a few lines of code, you can put those lines into a naked block and declare the variable inside that block. Of course, if you need the value of either `$n` or `$root` later, you would need to declare them in a larger scope.

You may have noticed the `sqrt` function in that code and wondered about it—yes, it’s a function we haven’t shown before. Perl has many built-in functions that are beyond the scope of this book. When you’re ready, check the [perlfunc documentation](#) to learn about more of them.

The `elsif` Clause

Every so often, you may need to check a number of conditional expressions, one after another, to see which one of them is true. This can be done with the `if` control structure’s `elsif` clause, as in this example:

```
if ( ! defined $dino) {
    print "The value is undef.\n";
} elsif ($dino =~ /^-?\d+\.\.?$/ ) {
    print "The value is an integer.\n";
} elsif ($dino =~ /^-?\d*\.\d+$/ ) {
    print "The value is a _simple_ floating-point number.\n";
} elsif ($dino eq '') {
    print "The value is the empty string.\n";
} else {
    print "The value is the string '$dino'.\n";
}
```

Perl will test the conditional expressions one after another. When one succeeds, the corresponding block of code is executed, and then the whole control structure is done and execution goes on to the rest of the program. If none has succeeded, the `else` block at the end is executed. (Of course, the `else` clause is still optional, although in this case it’s often a good idea to include it.)

There’s no limit to the number of `elsif` clauses, but remember that Perl has to evaluate the first 99 tests before it can get to the 100th. If you’ll have more than half a dozen `elsifs`, you should consider whether there’s a more efficient way to write it.

You may have noticed by this point that the keyword is spelled `elsif`, with only one `e`. If you write it as `elseif` with a second `e`, Perl will tell you it is not the correct spelling. Why? Because Larry says so.

Autoincrement and Autodecrement

You'll often want a scalar variable to count up or down by one. Since these are frequent constructs, there are shortcuts for them, like nearly everything else we do frequently.

The autoincrement operator (++) adds one to a scalar variable, like the same operator in C and similar languages:

```
my $bedrock = 42;
$bedrock++; # add one to $bedrock; it's now 43
```

Just like other ways of adding one to a variable, the scalar will be created if necessary:

```
my @people = qw{ fred barney fred wilma dino barney fred pebbles };
my %count; # new empty hash
$count{$_}++ foreach @people; # creates new keys and values as needed
```

The first time through that `foreach` loop, `$count{$_}` is incremented. That's `$count{"fred"}`, which thus goes from `undef` (since it didn't previously exist in the hash) up to 1. The next time through the loop, `$count{"barney"}` becomes 1; after that, `$count{"fred"}` becomes 2. Each time through the loop, you increment one element in `%count`, and possibly create it as well. After that loop finishes, `$count{"fred"}` is 3. This provides a quick and easy way to see which items are in a list and how many times each one appears.

Similarly, the autodecrement operator (--) subtracts one from a scalar variable:

```
$bedrock--; # subtract one from $bedrock; it's 42 again
```

The Value of Autoincrement

You can fetch the value of a variable and change that value at the same time. Put the ++ operator in front of the variable name to increment the variable first and then fetch its value. This is a *pre-increment*:

```
my $m = 5;
my $n = ++$m; # increment $m to 6, and put that value into $n
```

Or put the -- operator in front to decrement the variable first and then fetch its value. This is a *pre-decrement*:

```
my $c = --$m; # decrement $m to 5, and put that value into $c
```

Here's the tricky part. Put the variable name first to fetch the value first, then do the increment or decrement. This is called a *post-increment* or *post-decrement*:

```
my $d = $m++; # $d gets the old value (5), then increment $m to 6
my $e = $m--; # $e gets the old value (6), then decrement $m to 5
```

It's tricky because you're doing two things at once. You're fetching the value, and you're changing it in the same expression. If the operator is first, you increment (or decrement) first, then use the new value. If the variable is first, you return its (old) value first, then do the increment or decrement. Another way to say it is that these operators return a value, but they also have the side effect of modifying the variable's value.

If you write these in an expression on their own, not using the value but only the side effect, there's no difference whether you put the operator before or after the variable:

```
$bedrock++; # adds one to $bedrock
++$bedrock; # just the same; adds one to $bedrock
```

A common use of these operators is in connection with a hash, to identify an item you have seen before:

```

my @people = qw{ fred barney bamm-bamm wilma dino barney betty
pebbles };
my %seen;

foreach (@people) {
    print "I've seen you somewhere before, $_!\n"
        if $seen{$_}++;
}

```

When barney shows up for the first time, the value of `$seen{$_}++` is false, since it's the value of `$seen{$_}`, which is `$seen{"barney"}`, which is undef. But that expression has the side effect of incrementing `$seen{"barney"}`. When barney shows up again, `$seen{"barney"}` is now a true value, so you print the message.

The for Control Structure

Perl's `for` control structure is like the common `for` control structure you may have seen in other languages such as C. It looks like this:

```

for (initialization; test; increment) {
    body;
    body;
}

```

To Perl, though, this kind of loop is really a `while` loop in disguise, something like this:

```

initialization;
while (test) {
    body;
    body;
    increment;
}

```

The most common use of the `for` loop, by far, is for making computed iterations:

```
for ($i = 1; $i <= 10; $i++) { # count from 1 to 10
    print "I can count to $i!\n";
}
```

When you've seen these before, you'll know what the first line is saying even before you read the comment. Before the loop starts, the control variable, `$i`, is set to 1. Then the loop is really a `while` loop in disguise, looping while `$i` is less than or equal to 10. Between each iteration and the next is the increment, which here is a literal increment, adding one to the control variable, which is `$i`.

The first time through this loop, `$i` is 1. Since that's less than or equal to 10, you see the message. Although the increment is written at the top of the loop, it logically happens at the bottom of the loop, after printing the message. So, `$i` becomes 2, which is less than or equal to 10, so we print the message again, and `$i` is incremented to 3, which is less than or equal to 10, and so on.

Eventually, you print the message that your program can count to 9. Then you increment `$i` to 10, which is less than or *equal* to 10, so you run the loop one last time and print that your program can count to 10. Finally, you increment `$i` for the last time, to 11, which is not less than or equal to 10. So control drops out of the loop, and you're on to the rest of the program.

All three parts are together at the top of the loop so that it's easy for an experienced programmer to read that first line and say, "Ah, it's a loop that counts `$i` from 1 to 10."

Note that after the loop finishes, the control variable has a value "after" the loop. That is, in this case, the control variable has gone all the way to 11. This loop is very versatile, since you can make it count in all sorts of ways. For example, you can count down from 10 to 1:

```
for ($i = 10; $i >= 1; $i--) {
    print "I can count down to $i\n";
}
```

And this loop counts from -150 up to 1000 by threes:

```
for ($i = -150; $i <= 1000; $i += 3) {
    print "$i\n";
}
```

It never gets to 1000 exactly. The last iteration uses 999, since each value of `$i` is a multiple of three.

In fact, you could make any of the three control parts (initialization, test, or increment) empty if you wish, but you still need the two semicolons. In this (quite unusual) example, the test is a substitution, and the increment is empty:

```
for ($_ = "bedrock"; s/(.)/;; ) { # loops while the s/// is
    successful
    print "One character is: $1\n";
}
```

The test expression (in the implied `while` loop) is the substitution, which returns a true value if it succeeded. In this case, the first time through the loop, the substitution removes the `b` from `bedrock`. Each iteration removes another letter. When the string is empty, the substitution will fail, and the loop is done.

If the test expression (the one between the two semicolons) is empty, it's automatically true, making an infinite loop. But don't make an infinite loop like this until you see how to break out of such a loop, which we'll show later in this chapter:

```
for (;;) {
    print "It's an infinite loop!\n";
}
```

A more Perl-like way to write an intentional infinite loop, when you really want one, is with `while`:

```
while (1) {
    print "It's another infinite loop!\n";
}
```

If you somehow made an infinite loop that's gotten away from you, try Ctrl-C to halt your program.

Although C programmers are familiar with the first way, even a beginning Perl programmer should recognize that `1` is always true, making an intentional infinite loop, so the second is generally a better way to write it. Perl is smart enough to recognize a constant expression like that and optimize it away, so there's no difference in efficiency.

The Secret Connection Between `foreach` and `for`

It turns out that, inside the Perl parser, the keyword `foreach` is exactly equivalent to the keyword `for`. That is, any time Perl sees one of them, it's the same as if you had typed the other. Perl can tell which you meant by looking inside the parentheses. If you've got the two semicolons, it's a computed `for` loop (like we've just been talking about). If you don't have the semicolons, it's really a `foreach` loop:

```
for (1..10) { # really a foreach loop from 1 to 10
    print "I can count to $_!\n";
}
```

That's really a `foreach` loop, but it's written `for`. Perl figures it out based on what it finds in the parentheses. If it finds the semicolons, it's the C-style `for`. Except for this one example, throughout this book we'll spell out `foreach` wherever it appears. How you do it is an issue of your personal style.

In Perl, the true `foreach` loop is almost always a better choice. In the `foreach` loop (written `for`) in that previous example, it's easy to see at a glance that the loop will go from 1 to 10. But do you see what's wrong with this computed loop that's trying to do the same thing?

```
for ($i = 1; $i < 10; $i++) { # Oops! Something is wrong here!
    print "I can count to $i!\n";
}
```


You're going to make this error, probably for the rest of your life. Do you see it yet? You have the right numbers in the statement but your comparison is off. Since 10 is not less than 10, this version actually counts up to 9. This is an *off by one* error. You can fix that with a single character:

```
for ($i = 1; $i <= 10; $i++) { # OK now
    print "I can count to $i!\n";
}
```

Loop Controls

As you've surely noticed by now, Perl is one of the so-called "structured" programming languages. In particular, there's just one entrance to any block of code, which is at the top of that block. But there are times when you may need more control or versatility than what we've shown so far. For example, you may need to make a loop like a `while` loop, but one that always runs at least once. Or maybe you need to occasionally exit a block of code early. Perl has three loop control operators you can use in loop blocks to make the loop do all sorts of tricks.

The last Operator

The `last` operator immediately ends execution of the loop. (If you've used the "break" operator in C or a similar language, it's like that.) It's the "emergency exit" for loop blocks. When you hit `last`, the loop is done.

For example:

```
# Print all input lines mentioning fred, until the __END__ marker
while (<STDIN>) {
    if (/__END__/) {
        # No more input on or after this marker line
        last;
    } elsif (/fred/) {
        print;
    }
}
## last comes here ##
```

Once an input line has the `__END__` marker, that loop is done. Of course, that comment line at the end is merely a comment—it's not required in any way. We just threw that in to make it clearer what's happening.

There are five kinds of loop blocks in Perl. These are the blocks of `for`, `foreach`, `while`, `until`, and the naked block. The curly braces of an `if` block or subroutine don't qualify. As you may have noticed in this example, the `last` operator applied to the entire loop block.

The `last` operator will apply to the innermost currently running loop block. To jump out of outer blocks, stay tuned; that's coming up in a little bit.

The next Operator

Sometimes you're not ready for the loop to finish, but you're done with the current iteration. That's what the `next` operator is good for. It jumps to the *inside* of the bottom of the current loop block. After `next`, control continues with the next iteration of the loop (much like the `continue` operator in C or a similar language):

```
# Analyze words in the input file or files
while (<>) {
    foreach (split) { # break $_ into words, assign each to $_ in
turn
        $total++;
        next if /\W/; # strange words skip the remainder of the
loop
        $valid++;
        $count{$_}++; # count each separate word
        ## next comes here ##
    }
}

print "total things = $total, valid words = $valid\n";
foreach $word (sort keys %count) {
    print "$word was seen $count{$word} times.\n";
}
```

This one is a little more complex than most of our examples up to this point, so let's take it step by step. The `while` loop is reading lines of input from the diamond operator, one after another, into `$_`; you've seen that before. Each time through that loop, another line of input will be in `$_`.

Inside that loop, the `foreach` loop iterates over the return value of `split`. Do you remember the default for `split` with no arguments? That splits `$_` on whitespace, in effect breaking `$_` into a list of words. Since the `foreach` loop doesn't mention some other control variable, the control variable will be `$_`. So, you'll see one word after another in `$_`.

But didn't we just say that `$_` holds one line of input after another? Well, in the outer loop, that's what it holds. But inside the `foreach` loop, it holds one word after another. It's not a problem for Perl to reuse `$_` for a new purpose; this happens all the time.

Now, inside the `foreach` loop, you're seeing one word at a time in `$_`. `$total` is incremented, so it must be the total number of words. But the next line (which is the point of this example) checks to see whether the word has any nonword characters—anything but letters, digits, and underscores. So, if the word is `Tom's`, or if it is `full-sized`, or if it has an adjoining comma, quote mark, or any other strange character, it will match that pattern and you'll skip the rest of the loop, going on to the next word.

But let's say that it's an ordinary word, like `fred`. In that case, you count `$valid` up by one, and also `$count{$_}`, keeping a count for each different word. So, when you finish the two loops, you've counted every word in every line of input from every file the user wanted you to use.

We're not going to explain the last few lines. By now, we hope you've got stuff like that down already.

Like `last`, `next` may be used in any of the five kinds of loop blocks: `for`, `foreach`, `while`, `until`, or the naked block. Also, if you nest loop blocks, `next` works with the innermost one. You'll see how to change that at the end of this section.

The redo Operator

The third member of the loop control triad is `redo`. It says to go back to the top of the current loop block, without testing any conditional expression or advancing to the next iteration. (If you've used C or a similar language, you've never seen this one before. Those languages don't have this kind of operator.) Here's an example:

```
# Typing test
my @words = qw{ fred barney pebbles dino wilma betty };
my $errors = 0;

foreach (@words) {
    ## redo comes here ##
    print "Type the word '$_': ";
    chomp(my $try = <STDIN>);
    if ($try ne $_) {
        print "Sorry - That's not right.\n\n";
        $errors++;
        redo; # jump back up to the top of the loop
    }
}
print "You've completed the test, with $errors errors.\n";
```

Like the other two operators, `redo` will work with any of the five kinds of loop blocks, and it will work with the innermost loop block when they're nested.

The big difference between `next` and `redo` is that `next` will advance to the next iteration, but `redo` will redo the current iteration. Here's an example program that you can play with to get a feel for how these three operators work:

```
foreach (1..10) {
    print "Iteration number $_.\n\n";
    print "Please choose: last, next, redo, or none of the above?";
    chomp(my $choice = <STDIN>);
    print "\n";
    last if $choice =~ /last/i;
    next if $choice =~ /next/i;
    redo if $choice =~ /redo/i;
}
```

```

    print "That wasn't any of the choices... onward!\n\n";
}

print "That's all, folks!\n";

```

If you just press Return without typing anything (try it two or three times), the loop counts along from one number to the next. If you choose `last` when you get to number four, the loop is done, and you won't go on to number five. If you choose `next` when you're on four, you're on to number five without printing the “onward” message. And if you choose `redo` when you're on four, you're back to doing number four all over again.

Labeled Blocks

When you need to work with a loop block that's not the innermost one, use a label. Labels in Perl are like other identifiers—made of letters, digits, and underscores, but they can't start with a digit. However, since they have no prefix character, labels could be confused with the names of built-in function names, or even with your own subroutines' names. So it would be a poor choice to make a label called `print` or `if`. Because of that, Larry recommends that they be all uppercase. That not only ensures that the label won't conflict with another identifier but it also makes it easy to spot the label in the code. In any case, labels are rare, only showing up in a small percentage of Perl programs.

To label a loop block, just put the label and a colon in front of the loop. Then, inside the loop, you may use the label after `last`, `next`, or `redo`, as needed:

```

LINE: while (<>) {
    foreach (split) {
        last LINE if /__END__/;  # bail out of the LINE loop
        ...
    }
}

```

For readability, it's generally nice to put the label at the left margin, even if the current code is at a higher indentation. Notice that the label names the entire block; it's not marking a target point in the code. In that previous snippet of sample code, the special `__END__` token marks the end of all input. Once that token shows up, the program will ignore any remaining lines (even from other files).

It often makes sense to choose a noun as the name of the loop. That is, the outer loop is processing a line at a time, so we called it `LINE`. If we had to name the inner loop, we would have called it `WORD`, since it processes a word at a time. That makes it convenient to say things like “(move on to the) next `WORD`” or “redo (the current) `LINE`”:

```
LINE: while (<>) {
    WORD: foreach (split) {
        last LINE if /__END__/; # bail out of the LINE loop
        last WORD if /EOL/;     # skip the rest of the line
        ...
    }
}
```

The Conditional Operator

When Larry was deciding which operators to make available in Perl, he didn't want former C programmers to miss something that C had and Perl didn't, so he brought over all of C's operators to Perl. That meant bringing over C's most confusing operator: the conditional operator `? : .` While it may be confusing, it can also be quite useful.

The “conditional operator” is like an if-then-else test, all rolled into an expression. It's sometimes called a “ternary operator” because it takes three operands. It looks like this:

```
expression ? if_true_expr : if_false_expr
```

NOTE

Some people call the “conditional operator” the “ternary operator.” It does take three parts, and that’s enough to distinguish it from the other Perl operators. Older Perlers will still say “ternary,” but it’s not a good habit to develop if you don’t already have it.

First, Perl evaluates the expression to see whether it’s true or false. If it’s true, Perl returns the second expression; otherwise, it returns the third expression. Every time, one of the two expressions on the right is evaluated, and one is ignored. That is, if the first expression is true, then the second expression is evaluated, and the third is ignored. If the first expression is false, then the second is ignored, and the third is evaluated as the value of the whole thing.

In this example, the result of the subroutine `&is_weekend` determines which string expression you’ll assign to the variable:

```
my $location = &is_weekend($day) ? "home" : "work";
```

And here, you calculate and print out an average—or just a placeholder line of hyphens, if there’s no average available:

```
my $average = $n ? ($total/$n) : "-----";  
print "Average: $average\n";
```

You could always rewrite any use of the `? :` operator as an `if` structure, often much less conveniently and less concisely:

```
my $average;  
if ($n) {  
    $average = $total / $n;  
} else {  
    $average = "-----";  
}  
print "Average: $average\n";
```

Here’s a trick you might see used to code up a nice multiway branch:

```
my $size =
    ($width < 10) ? "small"   :
    ($width < 20) ? "medium"  :
    ($width < 50) ? "large"   :
    "extra-large"; # default
```

That is really just three nested `? :` operators, and it works quite well once you get the hang of it.

Of course, you're not obliged to use this operator. Beginners may wish to avoid it. But you'll see it in others' code sooner or later, and we hope that one day you'll find a good reason to use it in your own programs.

Logical Operators

As you might expect, Perl has all of the necessary logical operators needed to work with Boolean (true/false) values. For example, it's often useful to combine logical tests by using the logical AND operator (`&&`) and the logical OR operator (`||`):

```
if ($dessert{'cake'} && $dessert{'ice cream'}) {
    # Both are true
    print "Hooray! Cake and ice cream!\n";
} elsif ($dessert{'cake'} || $dessert{'ice cream'}) {
    # At least one is true
    print "That's still good...\n";
} else {
    # Neither is true; do nothing (we're sad)
}
```

There may be a shortcut. If the left side of a logical AND operation is false, the whole thing is false, since logical AND needs both sides to be true in order to return true. In that case, there's no reason to check the right side, so Perl doesn't evaluate it. Consider what happens in this example if `$hour` is 3:

```
if ( (9 <= $hour) && ($hour < 17) ) {
    print "Aren't you supposed to be at work...?\n";
}
```


Similarly, if the left side of a logical OR operation is true, Perl doesn't evaluate the right side. Consider what happens here if \$name is fred:

```
if ( ($name eq 'fred') || ($name eq 'barney') ) {  
    print "You're my kind of guy!\n";  
}
```

Because of this behavior, these operators are called “short-circuit” logical operators. They take a short circuit to the result whenever they can. In fact, it's fairly common to rely on this short-circuit behavior. Suppose you need to calculate an average:

```
if ( ($n != 0) && ($total/$n < 5) ) {  
    print "The average is below five.\n";  
}
```

In that example, Perl evaluates the right side only if the left side is true so that you can't accidentally divide by zero and crash the program (and we'll show you more about that in “**Trapping Errors**”).

The Value of a Short-Circuit Operator

Unlike what happens in C (and similar languages), the value of a short-circuit logical operator is the last part evaluated, not just a Boolean value. This provides the same result, in that the last part evaluated is always true when the whole thing should be true, and it's always false when the whole thing should be false.

But it's a much more useful return value. Among other things, the logical OR operator is quite handy for selecting a default value:

```
my $last_name = $last_name{$someone} || '(No last name)';
```

If \$someone is not listed in the hash, the left side will be undef, which is false. So the logical OR will have to look to the right side for the value, making the right side the default. In this idiom, the default value won't

merely replace `undef`; it would replace any false value equally well. You could fix that with the conditional operator:

```
my $last_name = defined $last_name{$someone} ?  
    $last_name{$someone} : '(No last name)';
```

That's too much work, and you had to say `$last_name{$someone}` twice. Perl 5.10 added a better way to do this, and it's discussed in the next section.

The defined-or Operator

In the previous section, you used the `||` operator to give a default value. That ignored the special case where the defined value was false but perfectly acceptable as a value. You then saw the uglier version using the conditional operator.

Perl 5.10 got around this sort of bug with the defined-or operator, `//`, which short-circuits when it finds a defined value, no matter if that value on the lefthand side is true or false. Even if someone's last name is `0`, this version still works because it won't replace defined values:

```
use v5.10;  
  
my $last_name = $last_name{$someone} // '(No last name)';
```

Sometimes you just want to give a variable a value if it doesn't already have one, and if it already has a value, to leave it alone. Suppose you want to only print messages if you set the `VERBOSE` environment variable. You check the value for the `VERBOSE` key in the `%ENV` hash. If it doesn't have a value, you want to give it one:

```
use v5.10;  
  
my $Verbose = $ENV{VERBOSE} // 0; # off by default  
print "I can talk to you!\n" if $Verbose;
```

You can see this in action by trying several values with `//` to see which ones pass through to the default value:

```
use v5.10;

foreach my $try ( 0, undef, '0', 1, 25 ) {
    print "Trying [$try] ---> ";
    my $value = $try // 'default';
    say "\tgot [$value]";
}
```

The output shows that you only get the default string when `$try` is `undef`:

```
Trying [0] --->      got [0]
Trying [] --->       got [default]
Trying [0] --->      got [0]
Trying [1] --->      got [1]
Trying [25] --->     got [25]
```

Sometimes you want to set a value when there isn't one already. For instance, when you have warnings enabled and try to print an undefined value, you get an annoying error:

```
use warnings;

my $name; # no value, so undefined!
printf "%s", $name; # Use of uninitialized value in printf ...
```

Sometimes that error is harmless. You could just ignore it, but if you expect that you might try to print an undefined value, you can use the empty string instead:

```
use v5.10;
use warnings;

my $name; # no value, so undefined!
printf "%s", $name // '';
```

Control Structures Using Partial-Evaluation Operators

The four operators that you've just seen—`&&`, `||`, `//`, and `?:`—all share a peculiar property: depending on the value on the left side, they may or may not evaluate an expression. Sometimes they evaluate the expression and sometimes they don't. For that reason, these are sometimes called *partial-evaluation* operators, since they may not evaluate all of the expressions around them. And partial-evaluation operators are automatically control structures. It's not as if Larry felt a burning need to add more control structures to Perl. But once he had decided to put these partial-evaluation operators into Perl, they automatically became control structures as well. After all, anything that can activate and deactivate a chunk of code is, by that very fact, a control structure.

Fortunately, you'll notice this only when the controlled expression has side effects, like altering a variable's value or causing some output. For example, suppose you ran across this line of code:

```
($m < $n) && ($m = $n);
```

Right away, you should notice that the result of the logical AND isn't being assigned anywhere. Why not?

If `$m` is really less than `$n`, the left side is true, so the right side will be evaluated, thereby doing the assignment. But if `$m` is not less than `$n`, the left side will be false, and thus the right side would be skipped. So that line of code would do essentially the same thing as this one, which is easier to understand:

```
if ($m < $n) { $m = $n }
```

Or maybe even:

```
$m = $n if $m < $n;
```

Or maybe you're fixing someone else's program, and you see a line like this one:

```
($m > 10) || print "why is it not greater?\n";
```

If `$m` is really greater than 10, the left side is true and the logical OR is done. But if it's not, the left side is false, and this will go on to print the message. Once again, this could (and probably should) be written in the traditional way, probably with `if` or `unless`. You most often see this sort of expression from people coming from the shell scripting world and transferring the idioms they know there into their new language.

If you have a particularly twisted brain, you might even learn to read these lines as if they were written in English. For example: check that `$m` is less than `$n`, *and if it is*, then do the assignment. Check that `$m` is more than 10, *or if it's not*, then print the message.

It's generally former C programmers or old-time Perl programmers who most often use these ways of writing control structures. Why do they do it? Some have the mistaken idea that these are more efficient. Some think these tricks make their code cooler. Some are merely copying what they saw someone else do.

In the same way, you can use the conditional operator for control. In this case, you want to assign `$x` to the smaller of two variables:

```
($m < $n) ? ($m = $x) : ($n = $x);
```

If `$m` is smaller, it gets `$x`. Otherwise, `$n` does.

There is another way to write the logical AND and logical OR operators. You may wish to write them out as words: `and` and `or`. These word operators have the same behaviors as the ones written with punctuation, but the words are down at the bottom of the precedence chart. Since the words don't "stick" so tightly to the nearby parts of the expression, they may need fewer parentheses:

```
$m < $n and $m = $n; # but better written as the corresponding  
if
```

There are also the low-precedence `not` (like the logical-negation operator, `!`) and the rare `xor`.

Then again, you may need *more* parentheses. Precedence is a bugaboo. Be sure to use parentheses to say what you mean, unless you're sure of the precedence. Nevertheless, since the word forms are very low precedence, you can generally understand that they cut the expression into big pieces, doing everything on the left first, and then (if needed) everything on the right.

Despite the fact that using logical operators as control structures can be confusing, sometimes they're the accepted way to write code. The idiomatic way of opening a file in Perl looks like this:

```
open my $fh, '<', $filename
or die "Can't open '$filename': $!";
```

By using the low-precedence short-circuit `or` operator, you tell Perl that it should “open this file...or die!” If the `open` succeeds, returning a true value, the `or` is complete. But if it fails, the false value causes the `or` to evaluate the part on the right, which will `die` with a message.

So, using these operators as control structures is part of idiomatic Perl—Perl as she is spoken. Used properly, they can make your code more powerful; otherwise, they can make your code unmaintainable. Don't overuse them.

Exercises

See “[Answers to Chapter 10 Exercises](#)” for answers to these exercises:

1. [25] Make a program that will repeatedly ask the user to guess a secret number from 1 to 100 until the user guesses the secret number. Your program should pick the number at random by using the magical formula `int(1 + rand 100)`. See what the [perlfunc documentation](#) says about `int` and `rand` if you're

curious about these functions. When the user guesses wrong, the program should respond “Too high” or “Too low.” If the user enters the word `quit` or `exit`, or if the user enters a blank line, the program should quit. Of course, if the user guesses correctly, the program should quit then as well!

2. [10] Modify the program from the previous exercise to print extra debugging information as it goes along, such as the secret number it chose. Make your change such that you can turn it off, but your program emits no warnings if you turn it off. If you are using Perl 5.10 or later, use the `//` operator. Otherwise, use the conditional operator.
3. [10] Modify the program from Exercise 3 in **Chapter 6** (the environment lister) to print `(undefined value)` for environment variables without a value. You can set the new environment variables in the program. Ensure that your program reports the right thing for variables with a false value. If you are using Perl 5.10 or later, use the `//` operator. Otherwise, use the conditional operator.

Chapter 11. Perl Modules

If there is a problem to solve, somebody has probably already solved it and made their solution available on the Comprehensive Perl Archive Network (CPAN), which is a worldwide collection of servers and mirrors containing thousands of modules of reusable Perl code. Indeed, most of Perl 5 is in the modules, since Larry designed it as an extensible language.

We're not going to teach you how to write modules here: you'll have to get that from *Intermediate Perl*. In this chapter, we will show you how to use modules that already exist. The idea is to get you started with CPAN rather than give you a survey on modules.

Finding Modules

Modules come in two types: those that come with Perl and that you should already have available to you, and those that you can get from CPAN to install yourself. Unless we say otherwise, the modules that we show come with Perl.

NOTE

Some vendors provide even more modules with their stock versions of Perl. There's actually a third type: vendor modules, but those are a bonus. Check your operating system to see what else you might have.

To find modules that don't come with Perl, start at [MetaCPAN](#). You can also browse the distribution and have a peek at the files without the bother of installing the modules. You can read the module documentation before you download the entire package. There are many other tools for inspecting a distribution too.

But before you go looking for a module, you should check if it is already installed. One way is to just try to read the documentation with *perldoc*. The `Digest::SHA` module comes with Perl (and we'll use it later), so you should be able to read its documentation:

```
$ perldoc Digest::SHA
```

Try it with a module that does not exist and you'll get an error message:

```
$ perldoc Llamas
No documentation found for "Llamas".
```

The documentation may be available in other formats (such as HTML) on your system too. If the documentation is there, you have the module installed.

The `cpan` command that comes with Perl can give you details on a module:

```
$ cpan -D Digest::SHA
```

Installing Modules

When you want to install a module that you don't already have, sometimes you can simply download the distribution, unpack it, and run a series of commands from the shell. There are two major build systems for Perl distributions, and you use them similarly. Check for a *README* or *INSTALL* file that gives you more information.

If the module uses `ExtUtils::MakeMaker`, which comes with Perl, the sequence will be something like this:

```
$ perl Makefile.PL
$ make install
```

If you can't install modules in the system-wide directories, you can specify another directory with an `INSTALL_BASE` argument to *Makefile.PL*:

```
$ perl Makefile.PL INSTALL_BASE=/Users/fred/lib
```

Some Perl module authors use another module, `Module::Build`, to build and install their creations. That sequence will be something like this:

```
$ perl Build.PL  
$ ./Build install
```

As before, you can specify an alternate installation directory:

```
$ perl Build.PL --install_base=/Users/fred/lib
```

Some modules depend on other modules, though, and they won't work unless you install yet more modules. Instead of doing all that work yourself, you can use one of the modules that come with Perl, `CPAN.pm`. From the command line, you can start up the `CPAN.pm` shell from which you can issue commands:

```
$ perl -MCPAN -e shell
```

NOTE

The “.pm” file extension stands for “Perl Module,” and some popular modules are pronounced with the “.pm” to distinguish them from something else. In this case, CPAN the archive is different than CPAN the module, so we say “CPAN.pm”.

Even this can be a little complicated, so a while ago one of our authors wrote a little script called *cpan*, which also comes with Perl and is usually installed with *perl* and its tools. Just call the script with a list of the modules you want to install:

```
$ cpan Module::CoreList Mojolicious Business::ISBN
```

There's another handy tool, *cpanm* (for *cpanminus*), although it doesn't come with *perl* (yet). It's designed as a zero-conf, lightweight CPAN client

that handles most of what people want to do. You can download the single file from <https://cpanmin.us> to get started.

Once you have *cpanm*, you simply tell it which modules you want to install:

```
$ cpanm DBI WWW::Mechanize
```

Using Your Own Directories

One of the common problems with Perl module installation is that by default, the CPAN tools want to install new modules into the same directories where *perl* is. You might not have the proper permissions to create new files in those directories.

The easiest way for beginners to keep additional Perl modules in their own directories is to use `local::lib`, which you'll have to get from CPAN since it doesn't come with *perl* (yet). This module sets the various environment variables that affect where CPAN clients install modules. You can see what they set by loading the module on the command line without anything else:

```
$ perl -Mlocal::lib
export PERL_LOCAL_LIB_ROOT="/Users/fred/perl5";
export PERL_MB_OPT="--install_base /Users/fred/perl5";
export PERL_MM_OPT="INSTALL_BASE=/Users/fred/perl5";
export PERL5LIB="...";
export PATH="/Users/fred/perl5/bin:$PATH";
```

NOTE

We haven't told you about command-line switches yet, but they are all in the [perlrun documentation](#).

The *cpan* client supports this if you use the `-I` switch to install modules:

```
$ cpan -I Set::CrossProduct
```

The *cpanm* tool is a bit smarter. If you've already set the same environment variables `local::lib` would set for you, it uses them. If not, it checks the default module directories for write permissions. If you don't have write permissions, it automatically uses `local::lib` for you.

Advanced users can configure their CPAN clients to install into whatever directories that they like too. You can set this in your `CPAN.pm` configuration so that modules automatically install in your private library directory when you use the `CPAN.pm` shell. You need to configure two settings, one each for the `ExtUtils::MakeMaker` and `Module::Build` systems:

```
$ cpan
cpan> o conf makepl_arg INSTALL_BASE=/Users/fred/perl5
cpan> o conf mbuild_arg "--install_base /Users/fred/perl5"
cpan> o conf commit
```

Notice these are the same settings that `local::lib` created for you in the environment. By setting them in the `CPAN.pm` configuration, it adds them every time it tries to install a module.

Once you've chosen where you want to put your Perl modules, you have to tell your programs where to find them. If you are using `local::lib`, you simply load that module in your program:

```
# inside your Perl program
use local::lib;
```

If you installed them in some other location, you can use the `lib` pragma with a list of additional module directories:

```
# also inside your Perl program
use lib qw( /Users/fred/perl5 );
```

As of v5.26, the **current directory is no longer part of the module search path**. Prior to that, Perl would look for modules in the current working directory (which might not be where your program is!). If your program

changed its working directory, loading more modules would look in that directory instead of where you started. This was a problem with security, so it's no longer there.

Most people probably want to look for modules in the same directory as their program—usually when they have written those modules instead of downloading them. In that case, the `FindBin` module, which comes with Perl, can help. It knows how to find the directory of your program, which you can then use to add your module directory to the search path:

```
use FindBin qw($Bin);
use lib "$Bin/../lib";
```

This is just enough to get you started. We talk much more about this in *Intermediate Perl*, where you also learn to make your own modules. You can also read the entries in the [perlfaq8 documentation](#).

Using Simple Modules

Suppose that you've got a long filename like `/usr/local/bin/perl` in your program, and you need to find out the basename without the directory portion. That's easy enough, since the basename is everything after the last slash (it's just `perl` in this case):

```
my $name = "/usr/local/bin/perl";
(my $basename = $name) =~ s#.#/##;
```

As you saw earlier, first Perl will do the assignment inside the parentheses, then it will do the substitution. The substitution is supposed to replace any string ending with a slash (that is, the directory name portion) with an empty string, leaving just the basename. You can even do this with the `/r` switch for the substitution operator:

```
use v5.14;
my $name = "/usr/local/bin/perl";
my $basename = $name =~ s#.#/##r;
```

And if you try these, it seems to work. Well, it *seems* to, but actually, there are three problems.

First, a Unix file or directory name could contain a newline character. (It's not something that's likely to happen by accident, but it's permitted.) So, since the regular expression dot (.) can't match a newline, a filename like the string `"/home/fred/flintstone\n/brontosaurus"` won't work right—that code would think the basename is

`"flintstone\n/brontosaurus"`. You could fix that with the `/s` option to the pattern (if you remembered about this subtle and infrequent case), making the substitution look like this: `s#.* /##s`.

The second problem is that this is Unix-specific. It assumes that the forward slash will always be the directory separator, as it is on Unix, and not the backslash or colon that some systems use. Although you might think that your work will never leak out from your Unix-only environment, most useful scripts (and some not so useful) tend to breed in the wild.

And the third (and biggest) problem with this is that we're trying to solve a problem someone else has already solved. Perl comes with a number of modules, which are smart extensions to Perl that add to its functionality. And if those aren't enough, there are many other useful modules available on CPAN, with new ones being added every week. You (or, better yet, your system administrator) can install them if you need their functionality.

In the rest of this section, we'll show you how to use some features of a couple simple modules that come with Perl. (There's more that these modules can do; this is just an overview to illustrate the general principles of how to use a simple module.)

Alas, we can't show you everything you'd need to know about using modules in general, since you'd have to understand advanced topics like references and objects in order to use some modules. As we'll see in the next few pages, though, you may be able to use a module that uses objects and references without having to understand those advanced topics. Those topics, including how to create a module, will be covered in great detail in *Intermediate Perl*. But this section should prepare you for using many

simple modules. Further information on some interesting and useful modules is included in [Appendix B](#).

The File::Basename Module

In the previous example, you found the basename of a filename in a way that's not portable. Something that seemed straightforward was susceptible to subtle mistaken assumptions (here, the assumption was that newlines would never appear in file or directory names). And you were reinventing the wheel, solving a problem that others have solved (and debugged) many times before you. Not to worry; it happens to all of us.

Here's a better way to extract the basename of a filename. Perl comes with a module called `File::Basename`. With the command *perldoc File::Basename*, or with your system's documentation, you can read about what it does. That's always the first step when using a new module. (It's often the third and fifth steps, as well.)

Soon you're ready to use it, so you declare it with a `use` directive near the top of your program:

```
use File::Basename;
```

NOTE

It's traditional to declare modules near the top of the file since that makes it easy for the maintenance programmer to see which modules you'll be using. That greatly simplifies matters when it's time to install your program on a new machine, for example.

During compilation, Perl sees that line and loads the module. Now it's as if Perl has some new functions that you may use in the remainder of your program. The one we wanted in the earlier example is the `basename` function itself:

```
use File::Basename;
```

```
my $name = "/usr/local/bin/perl";  
my $basename = basename $name; # gives 'perl'
```

Well, that worked for Unix. What if your program runs on MacPerl or Windows or VMS, to name a few? There's no problem—this module can tell which kind of machine you're using, and it uses that machine's filename rules by default. (Of course, you'd have that machine's kind of filename string in `$name`, in that case.)

There are some related functions also provided by this module. One is the `dirname` function, which pulls the directory name from a full filename. The module also lets you separate a filename from its extension, or change the default set of filename rules.

Using Only Some Functions from a Module

Suppose you discovered that when you went to add the `File::Basename` module to your existing program, you already have a subroutine called `&dirname`—that is, you already have a subroutine with the same name as one of the module's functions. Now there's trouble because the new `dirname` is *also* implemented as a Perl subroutine (inside the module). What do you do?

In your `use` declaration, simply give `File::Basename` an *import list* showing exactly which function names it should give you, and it'll supply those and no others. Here, you'll get nothing but `basename`:

```
use File::Basename qw/ basename /;
```

And here, you ask for no new functions at all:

```
use File::Basename qw/ /;
```

This is also frequently written as an empty set of parentheses:

```
use File::Basename ();
```


Why would you want to do that? Well, this directive tells Perl to load `File::Basename`, just as before, but not to *import* any function names. Importing lets you use the short, simple function names like `basename` and `dirname`. But even if you don't import those names, you can still use the functions. When they're not imported, though, you have to call them by their full names:

```
use File::Basename qw/ /;      # import no function names

my $betty = &dirname($wilma);  # uses your own subroutine
&dirname                        # (not shown)

my $name = "/usr/local/bin/perl";
my $dirname = File::Basename::dirname $name; # dirname from the
module
```

As you see, the full name of the `dirname` function from the module is `File::Basename::dirname`. You can always use the function's full name (once you've loaded the module), whether you've imported the short name `dirname` or not.

Most of the time, you'll want to use a module's default import list. But you can always override that with a list of your own, if you want to leave out some of the default items. Another reason to supply your own list would be if you wanted to import some function not on the default list, since most modules include some (infrequently needed) functions that are not on the default import list.

As you'd guess, some modules will, by default, import more symbols than others. Each module's documentation should make it clear which symbols it exports, if any, but you are always free to override the default import list by specifying one of your own, just as we did with `File::Basename`. Supplying an empty list imports no symbols.

The `File::Spec` Module

Now you can find out a file's basename. That's useful, but you'll often want to put that together with a directory name to get a full filename. For example, here you want to take a filename like */home/fred/ice-2.1.txt* and add a prefix to the basename:

```
use File::Basename;

print "Please enter a filename: ";
chomp(my $old_name = <STDIN>);

my $dirname = dirname $old_name;
my $basename = basename $old_name;

$basename =~ s/^/not/; # Add a prefix to the basename
my $new_name = "$dirname/$basename";

rename($old_name, $new_name)
    or warn "Can't rename '$old_name' to '$new_name': $!";
```

Do you see the problem here? Once again, you're making the assumption that filenames will follow the Unix conventions and use a forward slash between the directory name and the basename. Fortunately, Perl comes with a module to help with this problem too.

The `File::Spec` module is used for manipulating *file specifications*, which are the names of files, directories, and the other things that are stored on filesystems. Like `File::Basename`, it understands what kind of system it's running on, and it chooses the right set of rules every time. But unlike `File::Basename`, `File::Spec` is an object-oriented (often abbreviated "OO") module.

If you've never caught the fever of OO, don't let that bother you. If you understand objects, that's great; you can use this OO module. If you don't understand objects, that's OK, too. You just type the symbols as we show you, and it works just as if you knew what you were doing.

In this case, you learn from reading the documentation for `File::Spec` that you want to use a *method* called `catfile`. What's a method? It's just a different kind of function, as far as you're concerned here. The difference

is that you'll always call the methods from `File::Spec` with their full names, like this:

```
use File::Spec;

.
. # Get the values for $dirname and $basename as earlier
.

my $new_name = File::Spec->catfile($dirname, $basename);

rename($old_name, $new_name)
    or warn "Can't rename '$old_name' to '$new_name': $!";
```

As you can see, the full name of a method is the name of the module (called a *class* here), a small arrow (`->`), and the short name of the method. It is important to use the small arrow rather than the double-colon that we used with `File::Basename`.

Since you're calling the method by its full name, though, what symbols does the module import? None of them. That's normal for OO modules. So you don't have to worry about having a subroutine with the same name as one of the many methods of `File::Spec`.

Should you bother using modules like these? It's up to you, as always. If you're sure your program will never be run anywhere but on a Unix machine, say, and you're sure you completely understand the rules for filenames in Unix, then you may prefer to hardcode your assumptions into your programs. But these modules give you an easy way to make your programs more robust in less time—and more portable at no extra charge.

Path::Class

The `File::Spec` module does work with file paths from just about any platform, but the interface is a bit clunky. The `Path::Class` module, which doesn't come with Perl, gives you a more pleasant interface:

```
my $dir      = dir( qw(Users fred lib) );
my $subdir   = $dir->subdir( 'perl5' );    # Users/fred/lib/perl5
```

```
my $parent = $dir->parent; # Users/fred

my $windir = $dir->as_foreign( 'Win32' ); # Users\fred\lib
```

Databases and DBI

The DBI (Database Interface) module doesn't come with Perl, but it's one of the most popular modules since most people have to connect to a database of some sort. The beauty of DBI is that it allows you to use the same interface for just about any database server (or fake server, even), from simple comma-separated value files to enterprise servers such as Oracle. It has ODBC drivers, and some of its drivers are even vendor-supported. To get the full details, check out *Programming the Perl DBI* by Alligator Descartes and Tim Bunce (O'Reilly). You can also take a look at the [DBI website](#).

Once you install DBI, you also have to install a DBD (Database Driver). You can get a long list of DBDs from MetaCPAN. Install the right one for your database server, and ensure that you get the version that goes with the version of your server.

The DBI is an object-oriented module, but you don't have to know everything about OO programming to use it. You just have to follow the examples in the documentation. To connect to a database, you use the DBI module, then call its `connect` method:

```
use DBI;

$dbh = DBI->connect($data_source, $username, $password);
```

The `$data_source` contains information particular to the DBD that you want to use, so you'll get that from the DBD. For PostgreSQL, the driver is `DBD::Pg`, and the `$data_source` is something like:

```
my $data_source = "dbi:Pg:dbname=name_of_database";
```

Once you connect to the database, you go through a cycle of preparing, executing, and reading queries:

```
my $sth = $dbh->prepare("SELECT * FROM foo WHERE bla");
$sth->execute();
my @row_ary = $sth->fetchrow_array;
$sth->finish;
```

When you are finished, you disconnect from the database:

```
$dbh->disconnect();
```

The DBI can do all sorts of other things too. See its documentation for more details. Although it's a bit old, *Programming the Perl DBI* is still mostly a good introduction to the module.

Dates and Times

There are many modules that can handle dates and times for you, but the most popular is the `Time::Moment` module from Christian Hansen. It's a nearly complete solution for dates and times. You need to get this module from CPAN.

NOTE

If `Time::Moment` isn't enough for you, check out the `DateTime` module, which is a *complete* solution. It's a bit more heavyweight, but that's the price you pay.

Often, you will have the time as the system (or epoch) time, and you can easily convert that to a `Time::Moment` object:

```
use Time::Moment;
my $dt = Time::Moment->from_epoch( time );
```

Or skip the argument if you want the current time:

```
my $dt = Time::Moment->now;
```

From there, you can access various parts of the date to get what you need:

```
printf '%4d%02d%02d', $dt->year, $dt->month, $dt->day_of_month;
```

If you have two `Time::Moment` objects, you can do date math with them:

```
my $dt1 = Time::Moment->new(
    year      => 1987,
    month     => 12,
    day       => 18,
);

my $dt2 = Time::Moment->now;

my $years  = $dt1->delta_years( $dt2 );
my $months = $dt1->delta_months( $dt2 ) % 12;

printf "%d years and %d months\n", $years, $months;
```

For those dates, this gives you the output:

```
32 years and 8 months
```

Exercises

See “[Answers to Chapter 11 Exercises](#)” for answers to these exercises. Remember, you have to install some modules from CPAN, and part of these exercises require you to research the module by reading its documentation:

1. [15] Install the `Module::CoreList` module from CPAN (if you don’t already have it). Print a list of all the modules that came with v5.34. To build a hash whose keys are the names of the modules that came with a given version of *perl*, use this line:

```
my %modules = %{ $Module::CoreList::version{5.034} };
```

2. [20] Write a program using `Time::Moment` to compute the interval between now and a date that you enter as the year and month on the command line:

```
$ perl duration.pl 1960 9
60 years, 2 months
```

Chapter 12. File Tests

Earlier, we showed you how to open a filehandle for output. Normally, that creates a new file, wiping out any existing file with the same name. Perhaps you want to check that there isn't a file by that name. Perhaps you need to know how old a given file is. Or perhaps you want to go through a list of files to find which ones are larger than a certain number of bytes and have not been accessed for a certain amount of time. Perl has a complete set of tests you can use to find out information about files.

File Test Operators

Perl has a set of file test operators that let you get particular information about files. They all take the form of `-X`, where the `X` represents the particular test (and there is a literal `-X` file test operator too, to confuse things a bit). In most cases, these operators return true or false. Although we call these things operators, you'll find their documentation in [perlfunc](#).

NOTE

To get the list, use the command line `perldoc -f-X`. That `-X` is literal and not a command-line switch. It stands in for all the file test operators since you can't use `perldoc` to look them up individually.

Before you start a program that creates a new file, you might want to ensure that the file doesn't already exist so that you don't accidentally overwrite a vital spreadsheet datafile or that important birthday calendar. For this, you can use the `-e` file test, testing a filename for existence:

```
die "Oops! A file called '$filename' already exists.\n"
    if -e $filename;
```


Notice that you don't include `$!` in this `die` message, since you're not reporting that the system refused a request in this case. Here's an example of checking whether a file is being kept up-to-date. In this case, you're testing an already-opened filehandle instead of a string filename. Let's say that your program's configuration file should be updated every week or two. (Maybe it's checking for computer viruses.) If the file hasn't been modified in the past 28 days, something is wrong. The `-M` file test returns the file modification time in days before the start of the program, which seems like a mouthful until you see how convenient the code is:

```
warn "Config file is looking pretty old!\n"
  if -M CONFIG > 28;
```

The third example is more complex. Here, say that disk space is filling up, and rather than buy more disks, you decide to move any large, useless files to a backup. So let's go through our list of files to see which of them are larger than 100 K. But even if a file is large, you shouldn't warehouse it unless it hasn't been accessed in the last 90 days (so we know that it's not used too often). The `-s` file test operator, instead of returning true or false, returns the file size in bytes (and an existing file might have 0 bytes):

```
my @original_files = qw/ fred barney betty wilma pebbles dino
bamm-bamm /;
my @big_old_files; # The ones we want to put on backup tapes
foreach my $filename (@original_files) {
    push @big_old_files, $filename
        if -s $filename > 100_000 and -A $filename > 90;
}
```

There's a way to make this example more efficient, as you'll see by the end of the chapter.

The file tests all look like a hyphen and a letter, which is the name of the test, followed by either a filename or a filehandle to test. Many of them return a true/false value, but several give something more interesting. See [Table 12-1](#) for the complete list, and read the following explanation to learn more about the special cases.

Table 12-1. File tests and their meanings

File test	Meaning
-r	File or directory is readable by this (effective) user or group
-w	File or directory is writable by this (effective) user or group
-x	File or directory is executable by this (effective) user or group
-o	File or directory is owned by this (effective) user
-R	File or directory is readable by this real user or group
-W	File or directory is writable by this real user or group
-X	File or directory is executable by this real user or group
-O	File or directory is owned by this real user
-e	File or directory name exists
-z	File exists and has zero size (always false for directories)
-s	File or directory exists and has nonzero size (the value is the size in bytes)
-f	Entry is a plain file
-d	Entry is a directory
-l	Entry is a symbolic link
-S	Entry is a socket
-p	Entry is a named pipe (a “fifo”)
-b	Entry is a block-special file (like a mountable disk)
-c	Entry is a character-special file (like an I/O device)
-u	File or directory is setuid
-g	File or directory is setgid
-k	File or directory has the sticky bit set

File test	Meaning
-t	The filehandle is a TTY (as reported by the <code>isatty()</code> system function; filenames can't be tested by this test)
-T	File looks like a "text" file
-B	File looks like a "binary" file
-M	Modification age (measured in days)
-A	Access age (measured in days)
-C	Inode-modification age (measured in days)

The tests `-r`, `-w`, `-x`, and `-o` tell whether the given attribute is true for the effective user or group ID, which essentially refers to the person who is "in charge of" running the program.

NOTE

Note for advanced students: the corresponding `-R`, `-W`, `-X`, and `-O` tests use the real user or group ID, which becomes important if your program may be running set-ID; in that case, it's generally the ID of the person who requested running it. See any good book about advanced Unix programming for an explanation of set-ID programs.

These tests look at the "permission bits" on the file to see what is permitted. If your system uses access control lists (ACLs), the tests will use those as well. These tests generally tell whether the system would *try* to permit something, but it doesn't mean that it really would be possible. For example, `-w` may be true for a file on a CD-ROM, even though you can't write to it, or `-x` may be true on an empty file, which can't truly be executed.

The `-s` test does return true if the file is nonempty, but it's a special kind of true. It's the length of the file, measured in bytes, which evaluates as true for a nonzero number.

On a Unix filesystem there are seven types of items, represented by the seven file tests `-f`, `-d`, `-l`, `-S`, `-p`, `-b`, and `-c`. Any item should be one of those. But if you have a symbolic link pointing to a file, that will report true

for both `-f` and `-l`. So, if you want to know whether something is a symbolic link, you should generally test that first. (You'll learn more about symbolic links in [“Links and Files”](#).)

The age tests, `-M`, `-A`, and `-C` (yes, they're uppercase), return the number of days since the file was last modified, accessed, or had its inode changed. (The inode contains all the information about the file except for its contents—see the `stat` system call documentation or a good book on Unix internals for details.) This age value is a full floating-point number, so you might get a value of `2.00001` if a file had been modified two days and one second ago. (These “days” aren't necessarily the same as a human would count; for example, if it's 1:30 in the morning when you check a file modified about an hour before midnight, the value of `-M` for this file would be around `0.1`, even though it was modified “yesterday.”)

When checking the age of a file, you might even get a negative value like `-1.2`, which means that the file's last-access timestamp is set at about 30 hours in the future! The zero point on this timescale is the moment your program started running, so that value might mean that a long-running program was looking at a file that had just been accessed. Or a timestamp could be set (accidentally or intentionally) to a time in the future.

The tests `-T` and `-B` take a try at telling whether a file is text or binary. But people who know a lot about filesystems know that there's no bit (at least in Unix-like operating systems) to indicate that a file is a binary or text file—so how can Perl tell? The answer is that Perl cheats: it opens the file, looks at the first few thousand bytes, and makes an educated guess. If it sees a lot of null bytes, unusual control characters, and bytes with the high bit set, then that looks like a binary file. If there's not much weird stuff then it looks like text. As you might guess, it sometimes guesses wrong. It's not perfect, but if you just need to separate your source code from compiled files or HTML files from PNGs, these tests should do the trick.

You'd think that `-T` and `-B` would always disagree, since a text file isn't a binary and vice versa, but there are two special cases where they're in complete agreement. If the file doesn't exist or can't be read, both are false,

since it's neither a text file nor a binary. Alternatively, if the file is empty, it's an empty text file and an empty binary file at the same time, so they're both true.

The `-t` file test returns true if the given filehandle is a TTY—in short, if it's interactive because it's not a simple file or pipe. When `-t STDIN` returns true, it generally means that you can interactively ask the user questions. If it's false, your program is probably getting input from a file or pipe rather than a keyboard.

NOTE

The `IO::Interactive` module might be a better choice for this because the situation is actually a bit more complicated. That module explains this in its documentation.

Don't worry if you don't know what some of the other file tests mean—if you've never heard of them, you won't be needing them. But if you're curious, get a good book about programming for Unix. On non-Unix systems, these tests all try to give results analogous to what they do on Unix, or `undef` for an unavailable feature. Usually you'll be able to guess correctly what they'll do.

If you omit the filename or filehandle parameter to a file test (that is, if you have just `-r` or just `-s`, say), the default operand is the file named in `$_`. The `-t` file test is an exception, because that test isn't useful with filenames (they're never TTYs). By default, it tests `STDIN`. So, to test a list of filenames to see which ones are readable, you simply type:

```
foreach (@lots_of_filenames) {  
    print "$_ is readable\n" if -r; # same as -r $_  
}
```

But if you omit the parameter, be careful that whatever follows the file test doesn't look like it *could* be a parameter. For example, if you wanted to find

out the size of a file in kilobytes rather than in bytes, you might be tempted to divide the result of `-s` by 1000 (or 1024), like this:

```
# The filename is in $_
my $size_in_K = -s / 1000; # Oops!
```

When the Perl parser sees the slash, it doesn't think about division; since it's looking for the optional operand for `-s`, it sees what looks like the start of a regular expression in the forward slash. One simple way to prevent this kind of confusion is to put parentheses around the file test:

```
my $size_in_k = (-s) / 1024; # Uses $_ by default
```

Of course, it's always safe to explicitly give a file test a parameter:

```
my $size_in_k = (-s $filename) / 1024;
```

Testing Several Attributes of the Same File

You can use more than one file test on the same file to create a complex logical condition. Suppose you only want to operate on files that are both readable and writable; you check each attribute and combine them with `and`:

```
if (-r $filename and -w $filename) {
    ... }
```

This is an expensive operation, though. Each time you perform a file test, Perl asks the filesystem for all the information about the file (Perl's actually doing a `stat` each time, which we talk about in the next section). Although you already got that information when you tested `-r`, Perl asks for the same information again so that it can test `-w`. What a waste! This can be a significant performance problem if you're testing many attributes on many files.

Perl has a special shortcut to help you not do so much work. The virtual filehandle `_` (just the underscore) uses the information from the last file lookup that a file test operator performed. Perl only has to look up the file information once now:

```
if (-r $filename and -w _) {  
    ... }
```

You don't have to use the file tests next to each other to use `_`. Here we have them in separate `if` conditions:

```
if (-r $filename) {  
    print "The file is readable!\n";  
}  
  
if (-w _) {  
    print "The file is writable!\n";  
}
```

You have to watch out that you know what the last file lookup really was, though. If you do something else between the file tests, such as call a subroutine, the last file you looked up might be different. For instance, this example calls the `lookup` subroutine, which has a file test in it. When you return from that subroutine and do another file test, the `_` filehandle isn't for `$filename`, like you expect, but for `$other_filename`:

```
if (-r $filename) {  
    print "The file is readable!\n";  
}  
  
lookup( $other_filename );  
  
if (-w _) {  
    print "The file is writable!\n";  
}  
  
sub lookup {  
    return -w $_[0];  
}
```

Stacked File Test Operators

Prior to Perl 5.10, if you wanted to test several file attributes at the same time, you had to test them individually, even when using the `_` filehandle to save some work. Suppose you want to test if a file was readable and writable at the same time. You have to test if it's readable, then also test if it's writable:

```
if (-r $filename and -w _) {  
    print "The file is both readable and writable!\n";  
}
```

It's much easier to do this all at once. Starting with Perl 5.10, you can “stack” your file test operators by lining them all up before the filename:

```
use v5.10;  
  
if (-w -r $filename) {  
    print "The file is both readable and writable!\n";  
}
```

This stacked example is the same as the previous example with just a change in syntax, although it looks like the file tests are reversed. Perl does the file test nearest the filename first. Normally, this isn't going to matter.

Stacked file tests are especially handy for complex situations. Suppose you want to list all the directories that are readable, writable, executable, and owned by your user. You just need the right set of file tests:

```
use v5.10;  
  
if (-r -w -x -o -d $filename) {  
    print "My directory is readable, writable, and executable!\n";  
}
```

Stacked file tests aren't good for those tests that return values other than true or false that you would want to use in a comparison. You might think that this next bit of code first tests that it's a directory and then tests that it is less than 512 bytes, but it doesn't:


```
use v5.10;

if (-s -d $filename < 512) {      # WRONG! DON'T DO THIS
    say 'The directory is less than 512 bytes!';
}
```

Rewriting the stacked file tests as the previous notation shows us what is going on. The result of the combination of the file tests becomes the argument for the comparison:

```
if (( -d $filename and -s _ ) < 512) {
    print "The directory is less than 512 bytes!\n";
}
```

When the `-d` returns false, Perl compares that false value to 512. That turns out to be true since false will be 0, which just happens to be less than 512. Instead of worrying about that sort of confusion, you just write it as separate file tests to be nice to the maintenance programmers who come after you:

```
if (-d $filename and -s _ < 512) {
    print "The directory is less than 512 bytes!\n";
}
```

The stat and lstat Functions

While these file tests are fine for testing various attributes regarding a particular file or filehandle, they don't tell you the whole story. For example, there's no file test that returns the number of links to a file or the owner's user ID (uid). To get at the remaining information about a file, merely call the `stat` function, which returns pretty much everything that the `stat` Unix system call returns (hopefully more than you want to know).

NOTE

On a non-Unix system, both `stat` and `lstat`, as well as the file tests, should return “the closest thing available.” If `stat` or `lstat` fails, it will return an empty list. If the system call underlying a file test fails (or isn’t available on the given system), that test will generally return `undef`. See the [perlport documentation](#) for the latest about what to expect on different systems.

The operand to `stat` is a filehandle (including the `_` virtual filehandle), or an expression that evaluates to a filename. The return value is either the empty list, indicating that the `stat` failed (usually because the file doesn’t exist), or a 13-element list of numbers, most easily described using the following list of scalar variables:

```
my($dev, $ino, $mode, $nlink, $uid, $gid, $rdev,  
    $size, $atime, $mtime, $ctime, $blksize, $blocks)  
    = stat($filename);
```

The names here refer to the parts of the `stat` structure, described in detail in the `stat(2)` documentation. You should probably look there for the detailed descriptions. But in short, here’s a quick summary of the important ones:

\$dev and \$ino

The device number and inode number of the file. Together they make up a “license plate” for the file. Even if it has more than one name (hard link), the combination of device and inode numbers should always be unique.

\$mode

The set of permission bits for the file, and some other bits. If you’ve ever used the Unix command `ls -l` to get a detailed (long) file listing, you’ll see that each line of output contains something like `-rwxr-xr-x`. That information is wrapped up in `$mode`.

\$nlink

The number of (hard) links to the file or directory. This is the number of true names that the item has. This number is always 2 or more for directories and (usually) 1 for files. You'll see more about this when we talk about creating links to files in [Chapter 13](#). In the listing from `ls -l`, this is the number just after the permission-bits string.

\$uid and \$gid

The numeric user-ID and group-ID showing the file's ownership.

\$size

The size in bytes, as returned by the `-s` file test.

\$atime, \$mtime, and \$ctime

The three timestamps telling how many seconds have passed since the *epoch*, an arbitrary starting point for measuring system time. Some filesystems, such as *ext2*, may disable `atime` as a performance measure.

Invoking `stat` on the name of a symbolic link returns information on what the symbolic link points at, not information about the symbolic link itself (unless the link just happens to be pointing at nothing currently accessible). If you need the (mostly useless) information about the symbolic link itself, use `lstat` rather than `stat` (which returns the same information in the same order). If the operand isn't a symbolic link, `lstat` returns the same things that `stat` would.

Like the file tests, the operand of `stat` or `lstat` defaults to `$_`, meaning the underlying `stat` system call will be performed on the file named by the scalar variable `$_`.

NOTE

The `File::stat` module provides a friendlier interface to `stat`.

The localtime Function

When you have a timestamp number (such as the ones from `stat`), it will typically look something like 1454133253. That's not very useful for most humans, unless you need to compare two timestamps by subtracting. You may need to convert it to something human-readable, such as a string like "Sat Jan 30 00:54:13 2016." Perl can do that with the `localtime` function in a scalar context:

```
my $timestamp = 1454133253;
my $date = localtime $timestamp;
```

In a list context, `localtime` returns a list of numbers, several of which may not be quite what you'd expect:

```
my($sec, $min, $hour, $mday, $mon, $year, $wday, $yday, $isdst)
    = localtime $timestamp;
```

The `$mon` is a month number, ranging from 0 to 11, which is handy as an index into an array of month names. The `$year` is the number of years since 1900, oddly enough, so add 1900 to get the real year number. The `$wday` ranges from 0 (for Sunday) through 6 (for Saturday), and the `$yday` is the day of the year (ranging from 0 for January 1, through 364—or in the case of leap years, 365—for December 31).

There are two related functions that you'll also find useful. The `gmtime` function is just the same as `localtime`, except that it returns the time in Universal Time. If you need the current timestamp number from the system clock, just use the `time` function. Both `localtime` and `gmtime` default to using the current time value if you don't supply a parameter:

```
my $now = gmtime; # Get the current universal timestamp as a
string
```

For more on manipulating dates and times, see [Appendix B](#) for information about some useful modules.

Bitwise Operators

When you need to work with numbers bit-by-bit, as when working with the mode bits returned by `stat`, you'll need to use the bitwise operators. These are the operators that perform binary math operations on values. The *bitwise-and* operator (`&`) reports which bits are set in the left argument *and* in the right argument. For example, the expression `10 & 12` has the value 8. The bitwise-and needs to have a one-bit in both operands to produce a one-bit in the result. That means the bitwise-and operation on 10 (which is 1010 in binary) and 12 (which is 1100) gives 8 (which is 1000, with a one-bit only where the left operand has a one-bit *and* the right operand also has a one-bit). See [Figure 12-1](#).

$$\begin{array}{r} 1010 \\ \& 1100 \\ \hline 1000 \end{array}$$

Figure 12-1. Bitwise-and addition

The different bitwise operators and their meanings are shown in [Table 12-2](#).

Table 12-2. Examples of bitwise operations

Expression	Meaning
10 & 12	Bitwise-and—which bits are true in both operands (this gives 8)
10 12	Bitwise-or—which bits are true in one operand or the other (this gives 14)
10 ^ 12	Bitwise-xor—which bits are true in one operand or the other but not both (this gives 6)
6 << 2	Bitwise shift left—shift the left operand the number of bits shown by the right operand, adding zero-bits at the least-significant places (this gives 24)
25 >> 2	Bitwise shift right—shift the left operand the number of bits shown by the right operand, discarding the least-significant bits (this gives 6)
~ 10	Bitwise negation, also called unary bit complement, returns the number with the opposite bit for each bit in the operand (this gives 0xFFFFFFFF5, but see the text)

So, here's an example of some things you could do with the `$mode` returned by `stat`. The results of these bit manipulations could be useful with `chmod`, which you'll see in [Chapter 13](#):

```
# $mode is the mode value returned from a stat of CONFIG
warn "Hey, the configuration file is world-writable!\n"
  if $mode & 0002;                                # configuration
security problem
my $classical_mode = 0777 & $mode;                # mask off extra
high-bits
my $u_plus_x = $classical_mode | 0100;            # turn one bit on
my $go_minus_r = $classical_mode & (~ 0044);      # turn two bits
off
```

Using Bitstrings

All the bitwise operators can work with bitstrings as well as with integers. If either operand is an integer, the result will be an integer. (The integer will be at least a 32-bit integer, but it may be larger if your machine supports

that. That is, if you have a 64-bit machine, `~10` may give the 64-bit result, `0xFFFFFFFFFFFFFFFF5`, rather than the 32-bit result, `0xFFFFFFFF5`.)

But if both operands of a bitwise operator are strings, Perl will perform the operation on those bitstrings. That is, `"\xAA" | "\x55"` will give the string `"\xFF"`. Note that these values are single-byte strings; the result is a byte with all eight bits set. Bitstrings may be arbitrarily long.

This is one of the very few places where Perl distinguishes between strings and numbers. You can run into problems if you think you are doing number operations but give one of these operators two strings. Perl v5.22 adds a feature to fix this, but first you should understand the problem.

If Perl thinks either of the operands is a number, it does a numeric operation. Consider this code where you have `$number_str` that looks like a number but it's quoted like a string. So far, Perl thinks that's a string because we haven't done anything with it yet:

```
use v5.10;

my $number      = 137;
my $number_str  = '137';
my $string      = 'Amelia';

say "number_str & string: ", $number_str & $string;
say "number & string:      ", $number & $string;
say "number & number_str:  ", $number & $number_str;
say "number_str & string:  ", $number_str & $string;
```

Notice that the first and last `say` statements are the same. You haven't explicitly done anything to change the variables, and if you printed their values you'd see what you expected. But then why is this output so weird?

```
number_str & string:  ¿!%
number & string:      0
number & number_str:  137
number_str & string:  0
```

The first line of the output shows some gobbledygook from `'137' & 'Amelia'`. That's a string operation because both sides are strings.

The second output line shows that `137 & 'Amelia'` is zero. Since one of the operands is a number, Perl converts the other operand's value to its number form, which is 0. No bits are set in 0, so there are no bits set in common. The result is zero.

The same thing happens for the third line. The string `'137'` converts to the number 137, which is the same as the other argument. Since all of their set bits are the same, 137 is the answer.

Now it gets weird. When you redo the same operation you did for the first line of output you get a different answer! You didn't explicitly do anything to either value, but along the way Perl had to convert the values of `$number_str` and `$string` to a numeric form. When it did that, it secretly stored the result in case it had to do that again. When Perl does the last operation, it looks at the variables and sees that they have a numeric version, concludes that they are both numbers, and does a numeric bit operation. The numeric value of `$string` is 0 like the previous time we used it, so the answer is zero.

NOTE

Perl has the idea of a *dualvar*. A scalar can have separate numeric and string values at the same time. In most cases this is not a problem, and in some cases it's useful. For instance, the system error variable `$!` is a human-meaningful message as a string, but the system error number as a number. See the `Scalar::Util` module.

Perl v5.22 adds an experimental feature ([Appendix D](#)) to solve part of this problem. When you use an operator, you want to know what it's going to do no matter what path your operands took to get there. If you want a numeric bitwise operation, the `bitwise` feature makes the bitwise operations treat all operands as numbers:


```

use v5.22.0;
use feature qw(bitwise);
no warnings qw(experimental::bitwise);

my $number      = 137;
my $number_str  = '137';
my $string      = 'Amelia';

say "number_str & string:  ", $number_str & $string;
say "number & string:      ", $number      & $string;
say "number & number_str:  ", $number      & $number_str;
say "number_str & string:  ", $number_str & $string;

```

No gobbledygook in the first line of the output. Even though both operands are strings, Perl treats them as numbers:

```

number_str & string:  0
number & string:      0
number & number_str: 137
number_str & string:  0

```

If you wanted string bit operations instead, the `bitwise` feature adds new operators that look like the bitwise operators with a `.` after them:

```

use v5.22.0;
use feature qw(bitwise);
no warnings qw(experimental::bitwise);

my $number      = 137;
my $number_str  = '137';
my $string      = 'Amelia';

say "number_str &. string:  ", $number_str &. $string;
say "number &. string:      ", $number      &. $string;
say "number &. number_str:  ", $number      &. $number_str;
say "number_str &. string:  ", $number_str &. $string;

```

Now each of those is a string operation and each operand is converted to a string. The only result that seems to make sense is the one in the third line since it has '137' on each side of the `&.` operation:

```
number_str &. string:  ¿!%
number &. string:      ¿!%
number &. number_str:  137
number_str &. string:  ¿!%
```

Exercises

See “[Answers to Chapter 12 Exercises](#)” for answers to these exercises:

1. [15] Make a program that takes a list of files named on the command line and reports for each one whether it’s readable, writable, executable, or doesn’t exist. (Hint: it may be helpful to have a function that will do all the file tests for one file at a time.) What does it report about a file that has been *chmod*’ed to 0? (That is, if you’re on a Unix system, use the command `chmod 0 some_file` to mark that file as being neither readable, writable, nor executable.) In most shells, use a star as the argument to mean all the normal files in the current directory. That is, you could type something like `./ex12-1 *` to ask the program for the attributes of many files at once.
2. [10] Make a program to identify the oldest file named on the command line and report its age in days. What does it do if the list is empty (that is, if no files are mentioned on the command line)?
3. [10] Make a program that uses stacked file test operators to list all files named on the command line that are readable, writable, and owned by you.

Chapter 13. Directory Operations

The files you created in [Chapter 12](#) were generally in the same place as your program. But modern operating systems let you organize files into directories. Perl lets you manipulate these directories directly, in ways that are even fairly portable from one operating system to another.

Perl tries very hard to act the same no matter which system it runs on. Despite that, this chapter certainly shows Perl's preference toward its Unix history. If you are using Windows, you should look at the `Win32` distribution. Those modules provide hooks to the Win32 API.

The Current Working Directory

Your program runs with a *working directory*. This is the default directory for everything your program does.

With the `Cwd` module (part of the Standard Library), you can see what that directory is. Try this program, which we'll call *show_my_cwd*:

```
use v5.10;
use Cwd;
say "The current working directory is ", getcwd();
```

This should be the same directory that you'd get if you ran *pwd* in the Unix shell or *cd* (with no argument) in the Windows command shell. While you're practicing Perl with this book, you're most likely working in the same directory that holds your program.

When you open a file using a *relative path* (one that does not give the complete path from the top of the filesystem tree), Perl interprets that relative path starting at the current directory. Say that your current working

directory is */home/fred*. When you run this line of code to read a file, Perl looks for */home/fred/relative/path.txt*:

```
# relative to the current working directory
open my $fh, '<:utf8', 'relative/path.txt'
```

If you aren't using a shell or terminal program, the thing that runs your program might have a different idea about its current working directory. If you can run a program from your editor, that application might have a current working directory that is different from the one in which you've saved the file. Scheduling your program with something like *cron* probably does the same thing.

The current working directory is not necessarily the directory that holds the program. Both of these commands look for *my_program* in the current directory:

```
$ ./show_my_cwd
$ perl show_my_cwd
```

But you can run that program from another directory by giving it the full path to the program:

```
$ /home/fred/show_my_cwd
$ perl /home/fred/show_my_cwd
```

If you put your program in one of the directories your shell will search to find a program, you can run your program without any path hints from any directory you like:

```
$ show_my_cwd
```

NOTE

You can use the `File::Spec` module (part of the Standard Library) to convert between relative and absolute paths.

Changing the Directory

You may not want the current working directory that your program starts with. The `chdir` operator changes the working directory. It's just like the shell's `cd` command:

```
chdir '/etc' or die "cannot chdir to /etc: $!";
```

Because this is a system request, Perl sets the value of `$!` if an error occurs. You should normally check `$!` when `chdir` returns a false value since that indicates that something has not gone as requested.

The working directory is inherited by all processes that Perl starts (we'll talk more about that in [Chapter 15](#)). However, the change in working directory cannot affect the process that invoked Perl, such as the shell. You can change the current working directory for the currently running program and set that directory for processes you start, but you can't change it for the process that started your program. You can affect things at your level and below. This isn't a limitation on Perl's part; it's actually a feature of Unix, Windows, and other systems.

If you call `chdir` without an argument, Perl determines your home directory as best as possible and attempts to set the working directory to your home directory, similar to using the Unix `cd` command at the shell without a parameter. This is one of the few places where omitting the parameter doesn't use `$_` as the default. Instead, it looks in the environment variables `$ENV{HOME}` and `$ENV{LOGDIR}`, in that order. If neither is set, it does nothing.

NOTE

Some environments don't set these environment variables for you. The `File::HomeDir` module can help you set the environment variables that `chdir` will examine.

Older Perls let you use the empty string or `undef` (both false) as an argument to `chdir`, but that was deprecated with v5.12. If you want to change to the home directory, don't give `chdir` any argument.

Some shells permit you to use a tilde-prefixed path with `cd` to use another user's home directory as a starting point (like `cd ~fred`). This is a function of the shell, not the operating system, and Perl is calling the operating system directly. Thus, a tilde prefix will not work with `chdir`.

NOTE

You might try the `File::HomeDir` module to get the user's home directory in a mostly portable fashion.

Globbering

Normally, the shell expands any filename patterns on the command line into the matching filenames. This is called *globbing*. For example, if you give a filename pattern of `*.pm` to the Unix `echo` command, the shell expands this list to a list of names that match:

```
$ echo *.pm
barney.pm dino.pm fred.pm wilma.pm
```

The `echo` command doesn't have to know anything about expanding `*.pm`, because the shell has already expanded it. This works even for your Perl programs. Here's a program that simply prints its arguments:

```
foreach $arg (@ARGV) {
    print "one arg is $arg\n";
}
```

When you run this program with a glob as the single argument, the shell expands the glob before it sends the result to your program. Thus, you think you got many arguments:

```
$ perl show-args *.pm
one arg is barney.pm
one arg is dino.pm
one arg is fred.pm
one arg is wilma.pm
```

Note that `show-args` didn't need to know anything about globbing—the names were already expanded in `@ARGV`.

But sometimes you end up with a pattern like `*.pm` inside your Perl program. Can we expand this pattern into the matching filenames without working very hard? Sure—just use the `glob` operator:

```
my @all_files = glob '*';
my @pm_files = glob '*.pm';
```

Here, `@all_files` gets all the files in the current directory, alphabetically sorted, but doesn't get the files beginning with a period—just like the shell. And `@pm_files` gets the same list you got before by using `*.pm` on the command line.

In fact, anything you can say on the command line, you can also put as the (single) argument to `glob`, including multiple patterns separated by spaces:

```
my @all_files_including_dot = glob '.* *';
```

Here, you include an additional “dot star” parameter to get the filenames that begin with a dot as well as the ones that don't. Please note that the space between these two items inside the quoted string is significant, as it separates two different items you want to glob.

Windows users may be accustomed to using a glob of `*.*` to mean “all files.” But that actually means “all files with a dot in their names,” even in Perl in Windows.

The reason this works exactly as the shell works is that prior to v5.6, the `glob` operator simply called `/bin/csh` behind the scenes to perform the expansion. Because of this, globs were time consuming and could break in

large directories, or in some other cases. Conscientious Perl hackers avoided globbing in favor of directory handles, which we will show later in this chapter. However, if you're using a modern version of Perl, you should no longer be concerned about such things.

NOTE

Perl's built-in `glob` isn't your only option. The `File::Glob` module provides other forms that handle edge cases.

An Alternate Syntax for Globbing

Although we use the term *globbing* freely, and we talk about the `glob` operator, you might not see the word `glob` in very many of the programs that use globbing. Why not? Well, a lot of legacy code was written before the Perl developers gave the `glob` operator its name. Instead, it used the angle-bracket syntax, similar to reading from a filehandle:

```
my @all_files = <*>;      # exactly the same as my @all_files =  
glob "*";
```

Perl interpolates the value between the angle brackets similarly to a double-quoted string, which means that Perl expands variables to their current Perl values before being globbed:

```
my $dir = '/etc';  
my @dir_files = <$dir/* $dir/*.*>;
```

Here, you fetch all the nondot and dot files from the designated directory because `$dir` has been expanded to its current value.

So, if using angle brackets means both filehandle reading and globbing, how does Perl decide which of the two operators to use? Well, a filehandle has to be a Perl identifier or a variable. So, if the item between the angle

brackets is strictly a Perl identifier, it's a filehandle read; otherwise, it's a globbing operation. For example:

```
my @files = <FRED/*>;    # a glob
my @lines = <FRED>;      # a filehandle read
my @lines = <$fred>;     # a filehandle read
my $name = 'FRED';
my @files = <$name/*>;   # a glob
```

The one exception is if the contents are a simple scalar variable (not an element of a hash or array) that's not a filehandle object, then it's an *indirect filehandle read*, where the variable contents give the name of the filehandle you want to read:

```
my $name = 'FRED';
my @lines = <$name>; # an indirect filehandle read of FRED handle
```

The determination of whether it's a glob or a filehandle read happens at compile time, and thus it is independent of the content of the variables.

If you want, you can get the operation of an indirect filehandle read using the `readline` operator, which also makes it clearer:

```
my $name = 'FRED';
my @lines = readline FRED; # read from FRED
my @lines = readline $name; # read from FRED
```

But Perlers rarely use the `readline` operator, as indirect filehandle reads are uncommon and are generally performed against a simple scalar variable anyway.

Directory Handles

Another way to get a list of names from a given directory is with a *directory handle*. A directory handle looks and acts like a filehandle. You open it (with `opendir` instead of `open`), you read from it (with `readdir` instead of `readline`), and you close it (with `closedir` instead of

close). But instead of reading the *contents* of a file, you're reading the *names* of files (and other things) in a directory. For example:

```
my $dir_to_process = '/etc';
opendir my $dh, $dir_to_process or die "Cannot open
$dir_to_process: $!";
foreach $file (readdir $dh) {
    print "one file in $dir_to_process is $file\n";
}
closedir $dh;
```

Like filehandles, directory handles are automatically closed at the end of the program or if the directory handle is reopened onto another directory.

You can also use a bareword directory handle, just like you could with a filehandle, but this has the same drawbacks we wrote about earlier:

```
opendir DIR, $dir_to_process
    or die "Cannot open $dir_to_process: $!";
foreach $file (readdir DIR) {
    print "one file in $dir_to_process is $file\n";
}
closedir DIR;
```

This is a lower-level operation and we have to do more of the work ourselves. For example, the names are returned in no particular order. And the list includes all files, not just those matching a particular pattern (like *.pm from our globbing examples). So, if you wanted only the *pm*-ending files, you could use a skip-over function inside the loop:

```
while ($name = readdir $dh) {
    next unless $name =~ /\A\.pm\z/;
    ... more processing ...
}
```

Note here that the syntax is that of a regular expression, not a glob. And if you wanted all the nondot files, you could say that:

```
next if $name =~ /\A\./;
```

Or if you wanted everything but the common dot (current directory) and dot-dot (parent directory) entries, you could explicitly say that:

```
next if $name eq '.' or $name eq '..';
```

Here's another part that gets most people mixed up, so pay close attention. The filenames returned by the `readdir` operator have *no* pathname component. It's just the *name* within the directory. So, instead of */etc/hosts*, you get just *hosts*. And because this is another difference from the globbing operation, it's easy to see how people get confused.

So you need to patch up the name to get the full name:

```
opendir my $somedir, $dirname or die "Cannot open $dirname: $!";
while (my $name = readdir $somedir) {
    next if $name =~ /\A\./;          # skip over dot files
    $name = "$dirname/$name";        # patch up the path
    next unless -f $name and -r $name; # only readable files
    ...
}
```

For portability, you might want to use the `File::Spec::Functions` module that knows how to construct paths appropriate for the local system:

```
use File::Spec::Functions;

opendir my $somedir, $dirname or die "Cannot open $dirname: $!";
while (my $name = readdir $somedir) {
    next if $name =~ /\A\./;          # skip over dot files
    $name = catfile( $dirname, $name ); # patch up the path
    next unless -f $name and -r $name; # only readable files
    ...
}
```

NOTE

The `Path::Class` module is a nicer interface to the same thing, but it doesn't come with Perl.

Without the patch, the file tests would have been checking files in the current directory rather than in the directory named in `$dirname`. This is the single most common mistake when using directory handles.

Manipulating Files and Directories

Perl is commonly used to wrangle files and directories. Because Perl grew up in a Unix environment and still spends most of its time there, most of the description in this chapter may seem Unix centric. But the nice thing is that to whatever degree possible, Perl works exactly the same way on non-Unix systems.

Removing Files

Most of the time, you make files so that the data can stay around for a while. But when the data has outlived its usefulness, it's time to make the file go away. At the Unix shell level, you type an *rm* command to remove a file or files:

```
$ rm slate bedrock lava
```

In Perl, you use the `unlink` operator with a list of the files that you want to remove:

```
unlink 'slate', 'bedrock', 'lava';  
  
unlink qw(slate bedrock lava);
```

This sends the three named files away to bit heaven, never to be seen again.

The link is between a filename and something stored on the disk, but some filesystems allow multiple “hard” links to the data. The data is freed once all of those links disappear. `unlink` dissociates a file entry from the data. If that happens to be the last link, the filesystem can reuse that space.

Now, since `unlink` takes a list and the `glob` function returns a list, you can combine the two to delete many files at once:

```
unlink glob '*.o';
```

This is similar to `rm *.o` at the shell, except that you didn't have to fire off a separate `rm` process. So you can make those important files go away that much faster!

The return value from `unlink` tells you how many files have been successfully deleted. So, back to the first example, you can check its success:

```
my $successful = unlink "slate", "bedrock", "lava";  
print "I deleted $successful file(s) just now\n";
```

Sure, if this number is 3, you know it removed all the files, and if it's 0, it removed none of them. But what if it's 1 or 2? Well, there's no clue which ones had problems. If you need to know, do them one at a time in a loop:

```
foreach my $file (qw(slate bedrock lava)) {  
    unlink $file or warn "failed on $file: $!\n";  
}
```

Here, each file being deleted one at a time means the return value will be 0 (failed) or 1 (succeeded), which happens to look like a nice Boolean value, controlling the execution of `warn`. Using `or warn` is similar to `or die`, except that it's not fatal, of course (as we said back in [Chapter 5](#)). In this case, you put the newline on the end of the message to `warn` because it's not a bug in *your* program that causes the message.

When a particular `unlink` fails, Perl sets the `$!` variable to something related to the operating system error, which you can include in the message. This makes sense to use only when you're checking one filename at a time because the next operating system failed request resets the variable. You can't remove a directory with `unlink`, just like you can't remove a

directory with the simple `rm` invocation either. Look for the `rmdir` function coming up shortly for that.

Now, here's a little-known Unix fact. It turns out that you can have a file that you can't read, you can't write, you can't execute—maybe you don't even own the file—but you can still delete that file. The permission to unlink a file doesn't depend on the permission bits on the file itself; it's the permission bits on the directory that contains the file that matter.

We mention this because it's normal for a beginning Perl programmer, in the course of trying out `unlink`, to make a file, to `chmod` it to 0 (so that it's not readable or writable), and then to see whether this makes `unlink` fail. But instead it vanishes without so much as a whimper. If you really want to see a failed `unlink`, though, just try to remove `/etc/hosts` or a similar system file. Since that's a file controlled by the system administrator, you won't be able to remove it.

Renaming Files

Giving an existing file a new name is simple with the `rename` function:

```
rename 'old', 'new';
```

This is similar to the Unix `mv` command, taking a file named *old* and giving it the name *new* in the same directory. You can even move things around:

```
rename 'over_there/some/place/some_file', 'some_file';
```

Some people like to use the fat arrow that you saw in [Chapter 6](#) (“[The Big Arrow](#)”), so they remind themselves which way the rename happens:

```
rename 'over_there/some/place/some_file' => 'some_file';
```

This moves a file called `some_file` from another directory into the current directory, provided the user running the program has the appropriate

permissions and you aren't trying to copy files to another disk partition. This merely renames the file entry; it doesn't move any data.

Like most functions that request something of the operating system, `rename` returns false if it fails, and sets `$!` with the operating system error, so you can (and often should) use `or die` (or `or warn`) to report this to the user.

One frequent question is how to batch-rename a list of files, perhaps from those that end with *.old* to the same name with *.new*. Here's how to do it nicely in Perl:

```
foreach my $file (glob "*.old") {  
    my $newfile = $file;  
    $newfile =~ s/\.old\z/.new/;  
    if (-e $newfile) {  
        warn "can't rename $file to $newfile: $newfile exists\n";  
    } elsif (rename $file => $newfile) {  
        # success, do nothing  
    } else {  
        warn "rename $file to $newfile failed: $!\n";  
    }  
}
```

The check for the existence of `$newfile` is needed because `rename` will happily rename a file right over the top of an existing file, presuming the user has permission to remove the destination filename. You put the check in so that it's less likely that you'll lose information this way. Of course, if you *wanted* to replace existing files like *wilma.new*, you wouldn't bother testing with `-e` first.

Those first two lines inside the loop can be combined (and often are) to simply:

```
(my $newfile = $file) =~ s/\.old\z/.new/;
```

This works to declare `$newfile`, copy its initial value from `$file`, then modify `$newfile` with the substitution. You can read this as “transform

`$file` to `$newfile` using this replacement on the right.” And yes, because of precedence, those parentheses are required.

That’s a bit easier in Perl 5.14 with the `/r` flag to the `s///` operator. This line looks almost the same but lacks the parentheses:

```
use v5.14;

my $newfile = $file =~ s/\.old\z/.new/r;
```

Also, some programmers seeing this substitution for the first time wonder why the backslash is needed on the left but not on the right. The two sides aren’t symmetrical: the left part of a substitution is a regular expression, and the right part is a double-quoted string. So you use the pattern `/\.old$/` to mean “`.old` anchored at the end of the string” (anchored at the end because you don’t want to rename the *first* occurrence of `.old` in a file called *betty.old.old*), but on the right you can simply write `.new` to make the replacement.

Links and Files

To understand more about what’s going on with files and directories, it helps to understand the Unix model of files and directories, even if your non-Unix system doesn’t work in exactly this way. As usual, there’s more to the story than we’re able to explain here, so check any good book on Unix internal details if you need the full story.

A *mounted volume* is a hard disk drive (or something else that works more or less like that, such as a disk partition, a solid state device, a floppy disk, a CD-ROM, or a DVD-ROM). It may contain any number of files and directories. Each file is stored in a numbered *inode*, which we can think of as a particular piece of disk real estate. One file might be stored in inode 613, while another is in inode 7033.

To locate a particular file, though, you look it up in a directory. A directory is a special kind of file maintained by the system. Essentially, it is a table of

filenames and their inode numbers. Along with the other things in the directory, there are always two special directory entries. One is `.` (called “dot”), which is the name of that very directory; and the other is `..` (“dot-dot”), which is the directory one step higher in the hierarchy (i.e., the directory’s parent directory). **Figure 13-1** provides an illustration of two inodes. One is for a file called *chicken* and the other is Barney’s directory of poems, */home/barney/poems*, which contains that file. The file is stored in inode 613, while the directory is stored in inode 919. (The directory’s own name, *poems*, doesn’t appear in the illustration, because it’s stored in another directory.) The directory contains entries for three files (including *chicken*) and two directories (one of which is the reference back to the directory itself, in inode 919), along with each item’s inode number.

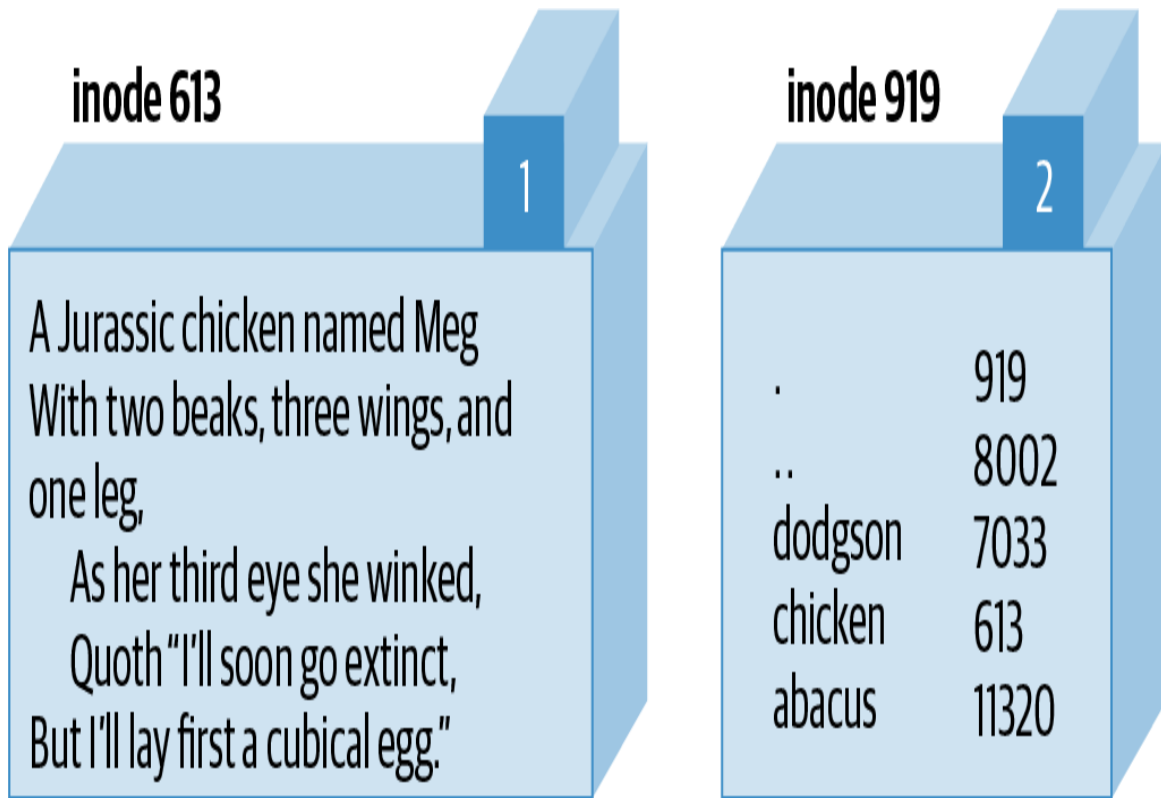


Figure 13-1. The chicken before the egg

When it’s time to make a new file in a given directory, the system adds an entry with the file’s name and the number of a new inode. How can the system tell that a particular inode is available, though? Each inode holds a number called its *link count*. The link count is always 0 if the inode isn’t

listed in any directory, so any inode with a link count of 0 is available for new file storage. When the inode is added to a directory, the link count is incremented; when the listing is removed, the link count is decremented. For the file *chicken* illustrated in **Figure 13-1**, the inode count of 1 is shown in the box above the inode's data.

But some inodes have more than one listing. For example, you've already seen that each directory entry includes `.`, which points back to that directory's own inode. So the link count for a directory should always be at least two: its listing in its parent directory and its listing in itself. In addition, if it has subdirectories, each of those will add a link, since each will contain `..`. In **Figure 13-1**, the directory's inode count of 2 is shown in the box above its data. A link count is the number of true names for the inode. Could an ordinary file inode have more than one listing in the directory? It certainly could. Suppose that, working in the directory shown in the figure, Barney uses the Perl `link` function to create a new link:

```
link 'chicken', 'egg'  
or warn "can't link chicken to egg: $!";
```

This is similar to typing `ln chicken egg` at the Unix shell prompt. If `link` succeeds, it returns true. If it fails, it returns false and sets `$!`, which Barney is checking in the error message. After this runs, the name *egg* is another name for the file *chicken*, and vice versa; neither name is “more real” than the other, and (as you may have guessed) it would take some detective work to find out which came first. **Figure 13-2** shows a picture of the new situation, where there are two links to inode 613.

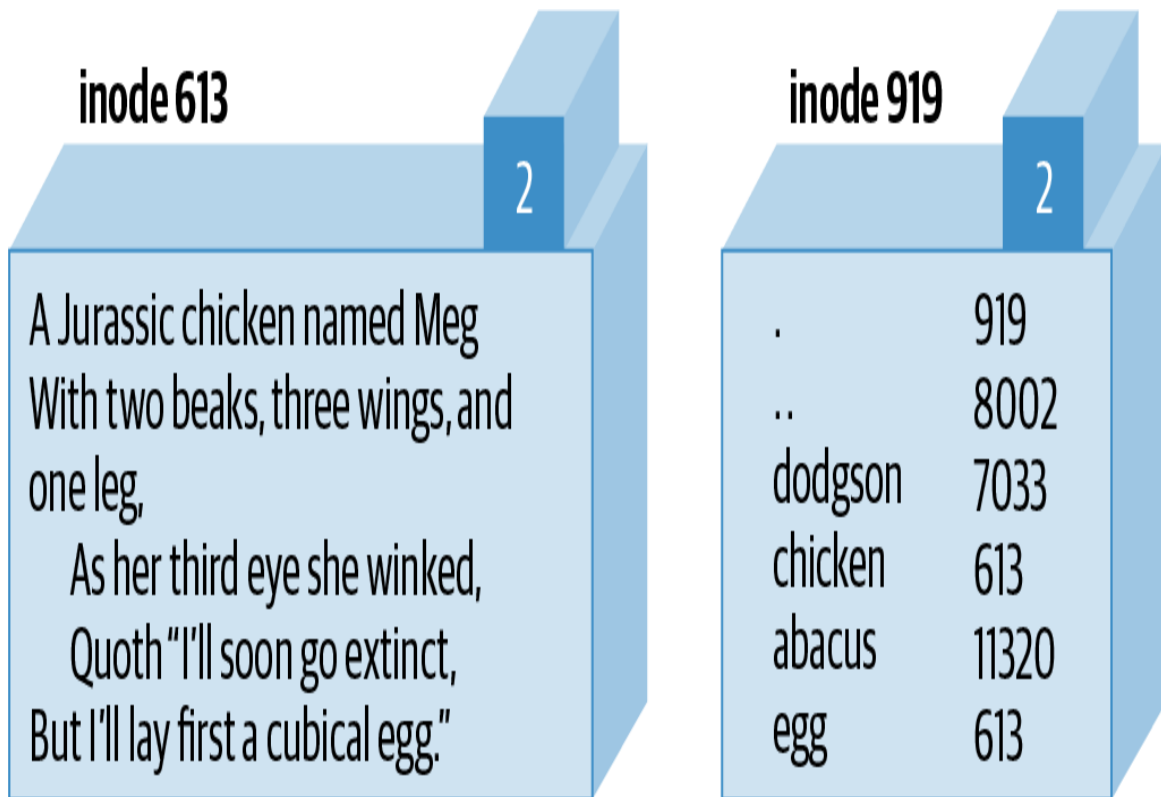


Figure 13-2. The egg is linked to the chicken

These two filenames are thus talking about the same place on the disk. If the file *chicken* holds 200 bytes of data, *egg* holds the same 200 bytes, for a total of 200 bytes (since it's really just one file with two names). If Barney appends a new line of text to the file *egg*, that line will also appear at the end of *chicken*. Now, if Barney were to accidentally (or intentionally) delete *chicken*, that data would not be lost—it's still available under the name *egg*. And vice versa: if he were to delete *egg*, he would still have *chicken*. Of course, if he were to delete both of them, the data would be lost. There's another rule about the links in directory listings: the inode numbers in a given directory listing all refer to inodes on that same mounted volume. This rule ensures that if you move the physical medium (a thumb drive, perhaps) to another machine, all the directories stick together with their files. That's why you can use `rename` to move a file from one directory to another, but only if both directories are on the same filesystem (mounted volume). If they were on different disks, the system would have to relocate

the inode's data, which is too complex an operation for a simple system call.

And yet another restriction on links is that they can't make new names for directories. That's because the directories are arranged in a hierarchy. If you were able to change that, utility programs like *find* and *pwd* could easily become lost trying to find their way around the filesystem.

So you can't add links to directories, and they can't cross from one mounted volume to another. Fortunately, there's a way to get around these restrictions on links, by using a new and different kind of link: a *symbolic link*. A symbolic link (also called a *soft link* to distinguish it from the true or *hard links* that we've been talking about up to now) is a special entry in a directory that tells the system to look elsewhere. Let's say that Barney (working in the same directory of poems as before) creates a symbolic link with Perl's `symlink` function, like this:

```
symlink 'dodgson', 'carroll'  
or warn "can't symlink dodgson to carroll: $!";
```

This is similar to what would happen if Barney used the command `ln -s dodgson carroll` from the shell. **Figure 13-3** shows a picture of the result, including the poem in inode 7033.

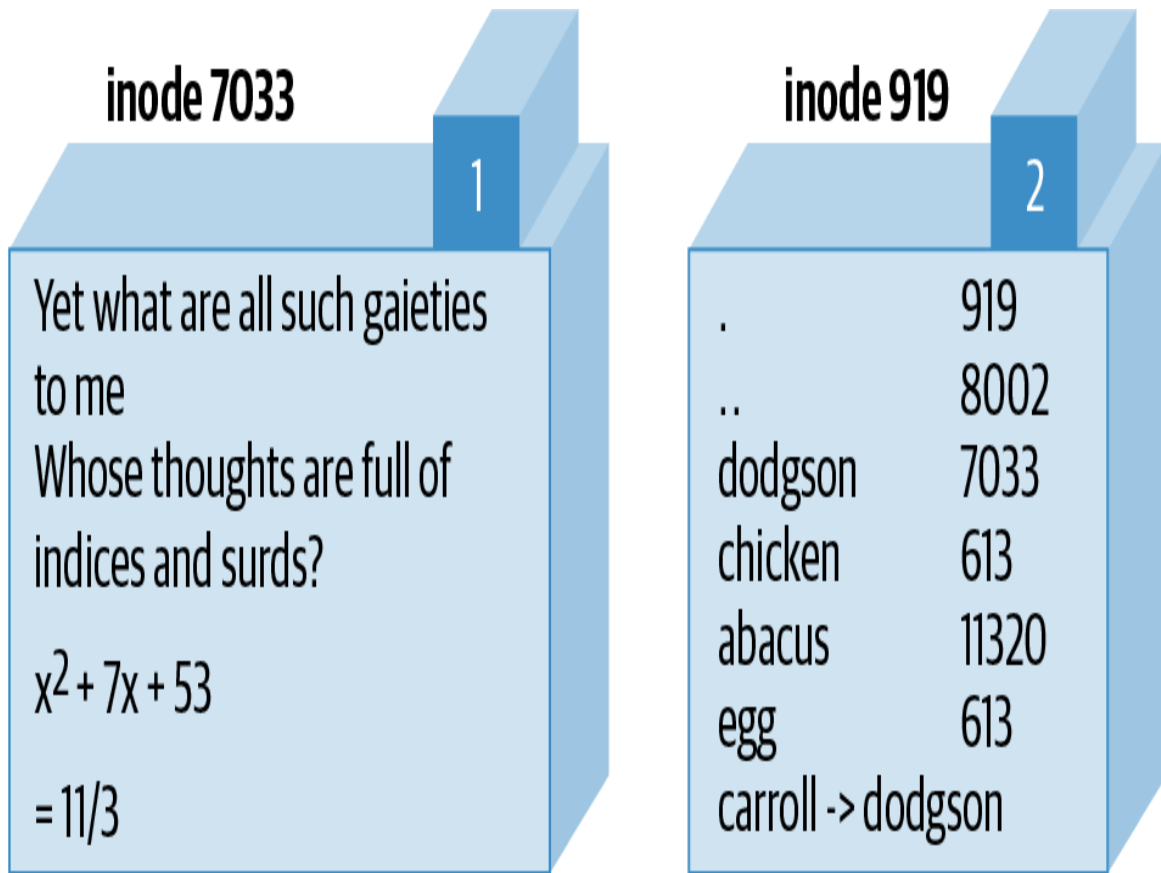


Figure 13-3. A symlink to inode 7033

Now if Barney chooses to read `/home/barney/poems/carroll`, he gets the same data as if he had opened `/home/barney/poems/dodgson` because the system follows the symbolic link automatically. But that new name isn't the "real" name of the file because (as you can see in the diagram) the link count on inode 7033 is still just one. That's because the symbolic link simply tells the system, "If you got here looking for *carroll*, now you want to go off to find something called *dodgson* instead."

A symbolic link can freely cross mounted filesystems or provide a new name for a directory, unlike a hard link. In fact, a symbolic link could point to any filename, one in this directory or in another one—or even to a file that doesn't exist! But that also means that a soft link can't keep data from being lost as a hard link can, since the symlink doesn't contribute to the link count. If Barney were to delete *dodgson*, the system would no longer be

able to follow the soft link. Even though there would still be an entry called *carroll*, trying to read from it would give an error like `file not found`. The file test `-l 'carroll'` would report true, but `-e 'carroll'` would be false: it's a symlink, but its target doesn't exist. Deleting *carroll* would merely remove the symlink, of course.

Since a soft link could point to a file that doesn't yet exist, it could be used when creating a file as well. Barney has most of his files in his home directory, */home/barney*, but he also needs frequent access to a directory with a long name that is difficult to type: */usr/local/opt/system/httpd/root-dev/users/staging/barney/cgi-bin*. So he sets up a symlink named */home/barney/my_stuff*, which points to that long name, and now it's easy for him to get to it. If he creates a file (from his home directory) called *my_stuff/bowling*, that file's real name is */usr/local/opt/system/httpd/root-dev/users/staging/barney/cgi-bin/bowling*. Next week, when the system administrator moves these files of Barney's to */usr/local/opt/internal/httpd/www-dev/users/staging/barney/cgi-bin*, Barney just repoints the one symlink, and now he and all of his programs can still find his files with ease.

It's normal for either */usr/bin/perl* or */usr/local/bin/perl* (or both) to be symbolic links to the true Perl binary on your system. This makes it easy to switch to a new version of Perl. Say you're the system administrator, and you've built the new Perl. Of course, your older version is still running and you don't want to disrupt anything. When you're ready for the switch, you simply move a symlink or two, and now every program that begins with *#!/usr/bin/perl* will automatically use the new version. In the unlikely case that there's some problem, it's a simple thing to replace the old symlinks and have the older Perl running the show again. (But like any good admin, you notified your users to test their code with the new */usr/bin/perl-7.2* well in advance of the switch, and you told them they can keep using the older one during the next month's grace period by changing their programs' first lines to *#!/usr/bin/perl-6.1*, if they need to.)

Perhaps surprisingly, both hard and soft links are very useful. Many non-Unix operating systems have neither, and the lack is sorely felt. On some

non-Unix systems, symbolic links may be implemented as a “shortcut” or an “alias”—check the [perlport documentation](#) for the latest details.

To find out where a symbolic link is pointing, use the `readlink` function. This will tell you where the symlink leads, or it will return `undef` if its argument wasn’t a symlink:

```
my $where = readlink 'carroll';           # Gives "dodgson"

my $perl = readlink '/usr/local/bin/perl'; # Maybe tells where
perl is
```

You can remove either kind of link with `unlink`—and now you see where that operation gets its name. `unlink` simply removes the directory entry associated with the given filename, decrementing the link count and thus possibly freeing the inode.

Making and Removing Directories

Making a directory inside an existing directory is easy. Just invoke the `mkdir` function:

```
mkdir 'fred', 0755 or warn "Cannot make fred directory: $!";
```

Again, true means success, and Perl sets `$!` on failure.

But what’s that second parameter, `0755`? That’s the initial permission setting on the newly created directory (you can always change it later). The value here is specified as an octal because the value will be interpreted as a Unix permission value, which has a meaning based on groups of three bits each, and octal values represent that nicely. Yes, even in Windows or MacPerl, you still need to know a little about Unix permission values to use the `mkdir` function. Mode `0755` is a good one to use because it gives you full permission, but lets everyone else have read access but no permission to change anything.

The `mkdir` function doesn't require you to specify this value in octal—it's just looking for a numeric value (either a literal or a calculation). But unless you can quickly figure that 0755 octal is 493 decimal in your head, it's probably easier to let Perl calculate that. And if you accidentally leave off the leading zero, you get 755 decimal, which is 1363 octal, a strange permission combination indeed.

As you saw earlier (in [Chapter 2](#)), a string value being used as a number is never interpreted as octal, even if it starts with a leading zero. So this doesn't work:

```
my $name = "fred";
my $permissions = "0755"; # danger...this isn't working
mkdir $name, $permissions;
```

Oops, you just created a directory with the bizarre 01363 permissions because 0755 was treated as a decimal. To fix that, use the `oct()` function, which forces octal interpretation of a string whether or not there's a leading zero:

```
mkdir $name, oct($permissions);
```

Of course, if you are specifying the permission value directly within the program, just use a number instead of a string. The need for the extra `oct()` function shows up most often when the value comes from user input. For example, suppose you take the arguments from the command line:

```
my ($name, $perm) = @ARGV; # first two args are name,
permissions
mkdir $name, oct($perm) or die "cannot create $name: $!";
```

The value here for `$perm` is initially interpreted as a string, and thus the `oct()` function interprets the common octal representation properly.

To remove empty directories, use the `rmdir` function in a manner similar to the `unlink` function, although it can only remove one directory per call:


```
foreach my $dir (qw(fred barney betty)) {
    rmdir $dir or warn "cannot rmdir $dir: $!\n";
}
```

The `rmdir` operator fails for nonempty directories. As a first pass, you can attempt to delete the contents of the directory with `unlink`, then try to remove what should now be an empty directory. For example, suppose you need a place to write many temporary files during the execution of a program:

```
my $temp_dir = "/tmp/scratch_$$";          # based on process ID;
see the text
mkdir $temp_dir, 0700 or die "cannot create $temp_dir: $!";
...
# use $temp_dir as location of all temporary files
...
unlink glob "$temp_dir/* $temp_dir/*.*"; # delete contents of
$temp_dir
rmdir $temp_dir;                          # delete now-empty
directory
```

NOTE

If you really need to create temporary directories or files, check out the `File::Temp` module, which comes with Perl.

The initial temporary directory name includes the current process ID, which is unique for every running process and is accessed with the `$$` variable (similar to the shell). You do this to avoid colliding with any other processes, as long as they also include their process IDs as part of their pathnames. (In fact, it's common to use the program's name as well as the process ID, so if the program is called *quarry*, the directory would probably be something like `/tmp/quarry_$$`.)

At the end of the program, that last `unlink` should remove all the files in this temporary directory, and then the `rmdir` function can delete the now-empty directory. However, if you've created subdirectories under that directory, the `unlink` operator fails on those, and the `rmdir` also fails.

For a more robust solution, check out the `remove_tree` function provided by the `File::Path` module of the standard distribution.

Modifying Permissions

The Unix `chmod` command changes the permissions on a file or directory. Similarly, Perl has the `chmod` function to perform this task:

```
chmod 0755, 'fred', 'barney';
```

As with many of the operating system interface functions, `chmod` returns the number of items successfully altered, and when used with a single argument, sets `$!` in a sensible way for error messages when it fails. The first parameter is the Unix permission value (even for non-Unix versions of Perl). For the same reasons we presented earlier in describing `mkdir`, this value is usually specified in octal.

Symbolic permissions (like `+x` or `go=u-w`) accepted by the Unix *chmod* command are not valid for the `chmod` function.

NOTE

The `File::chmod` module from CPAN can upgrade the `chmod` operator to understand symbolic mode values.

Changing Ownership

If the operating system permits it, you may change the ownership and group membership of a list of files (or filehandles) with the `chown` function. The user and group are both changed at once, and both have to be the numeric user ID and group ID values. For example:

```
my $user  = 1004;  
my $group = 100;
```

```
chown $user, $group, glob '*.o';
```

What if you have a username like `merlyn` instead of the number? Simple. Just call the `getpwnam` function to translate the name into a number, and the corresponding `getgrnam` to translate the group name into its number:

```
defined(my $user = getpwnam 'merlyn') or die 'bad user';  
defined(my $group = getgrnam 'users') or die 'bad group';  
chown $user, $group, glob '/home/merlyn/*';
```

The `defined` function verifies that the return value is not `undef`, which will be returned if the requested user or group is not valid.

The `chown` function returns the number of files affected, and it sets `$!` on error.

Changing Timestamps

In those rare cases when you want to lie to other programs about when a file was most recently modified or accessed, you can use the `utime` function to fudge the books a bit. The first two arguments give the new access time and modification time, while the remaining arguments are the list of filenames to alter those timestamps. The times are specified in internal timestamp format (the same type of values returned from the `stat` function that we mentioned in “[The stat and lstat Functions](#)”).

One convenient value to use for the timestamps is “right now,” returned in the proper format by the `time` function. To update all the files in the current directory to look like they were modified a day ago, but accessed just now, you could simply do this:

```
my $now = time;  
my $ago = $now - 24 * 60 * 60; # seconds per day  
utime $now, $ago, glob '*';    # set access to now, mod to a day  
ago
```

Of course, nothing stops you from creating a file that is arbitrarily stamped far in the future or past (within the limits of the Unix timestamp values of 1970 to 2038, or whatever your non-Unix system uses, unless you have 64-bit timestamps). Maybe you could use this to create a directory where you keep your notes for that time-travel novel you're writing.

The third timestamp (the `ctime` value) is always set to “now” whenever anything alters a file, so there's no way to set it (it would have to be reset to “now” after you set it) with the `utime` function. That's because its primary purpose is for incremental backups: if the file's `ctime` is newer than the date on the backup tape, it's time to back it up again.

Exercises

The programs here are potentially dangerous! Be careful to test them in a mostly empty directory to make it difficult to accidentally delete something useful.

See “[Answers to Chapter 13 Exercises](#)” for answers to these exercises:

1. [12] Write a program to ask the user for a directory name, then change to that directory. If the user enters a line with nothing but whitespace, change to their home directory as a default. After changing, list the ordinary directory contents (not the items whose names begin with a dot) in alphabetical order. (Hint: will that be easier to do with a directory handle or with a glob?) If the directory change doesn't succeed, just alert the user—but don't try showing the contents.
2. [4] Modify the program to include all files, not just the ones that don't begin with a dot.
3. [5] If you used a directory handle for the previous exercise, rewrite it to use a glob. Or if you used a glob, try it now with a directory handle.

4. [6] Write a program that works like *rm*, deleting any files named on the command line. (You don't need to handle any of the options of *rm*.)
5. [10] Write a program that works like *mv*, renaming the first command-line argument to the second command-line argument. (You don't need to handle any of the options of *mv* or additional arguments.) Remember to allow for the destination to be a directory; if it is, use the same original basename in the new directory.
6. [7] If your operating system supports it, write a program that works like *ln*, making a hard link from the first command-line argument to the second. (You don't need to handle options of *ln* or more arguments.) If your system doesn't have hard links, just print out a message telling which operation you would perform if it were available. Hint: this program has something in common with the previous one—recognizing that could save you time in coding.
7. [7] If your operating system supports it, fix up the program from the previous exercise to allow an optional *-s* switch before the other arguments to indicate that you want to make a soft link instead of a hard link. (Even if you don't have hard links, see whether you can at least make soft links with this program.)
8. [7] If your operating system supports it, write a program to find any symbolic links in the current directory and print out their values (like *ls -l* would: `name -> value`).

Chapter 14. Strings and Sorting

As we mentioned near the beginning of this book, Perl is designed to be good at solving programming problems that are about 90% working with text and 10% everything else. So it's no surprise that Perl has strong text-processing abilities, even without all that you've done with regular expressions. Sometimes the regular expression engine is too fancy and you need a simpler way of working with a string, as you'll see in this chapter.

Finding a Substring with `index`

Finding a substring depends on where you lost it. If you happen to have lost it within a bigger string, you're in luck because the `index` function can help you out. Here's how it looks:

```
my $where = index($big, $small);
```

Perl locates the first occurrence of the small string within the big string, returning an integer location of the first character. The character position returned is a zero-based value: if the substring is found at the very beginning of the string, `index` returns 0; if it's one character later, the return value is 1, and so on. If `index` can't find the substring at all, it returns -1 to indicate that. In this example, `$where` gets 6 because that's the position where `wor` starts:

```
my $stuff = "Howdy world!";  
my $where = index($stuff, "wor");
```

Another way you could think of the position number is the number of characters to skip over before getting to the substring. Since `$where` is 6, you know that you have to skip over the first six characters of `$stuff` before you find `wor`.

The `index` function will always report the location of the *first found* occurrence of the substring. But you can tell it to start searching at a later point than the start of the string by using the optional third parameter, which tells `index` to start at that position:

```
my $stuff = "Howdy world!";
my $where1 = index($stuff, "w");           # $where1 gets 2
my $where2 = index($stuff, "w", $where1 + 1); # $where2 gets 6
my $where3 = index($stuff, "w", $where2 + 1); # $where3 gets -1
(not found)
```

That third parameter is effectively giving a minimum value for the return value; if the substring isn't at that position or later, `index` returns `-1`. You probably wouldn't do this without a loop, though. In this example, we use an array to store the positions:

```
use v5.10;

my $stuff = "Howdy world!";

my @where = ();
my $where = -1;
while( 1 ) {
    $where = index( $stuff, 'w', $where + 1 );
    last if $where == -1;
    push @where, $where;
}
say "Positions are @where";
```

We initialize `$where` to `-1` because we'll add 1 to it before we pass the starting position to `index`. This means that the first pass is not a special case.

Once in a while, you might prefer to have the last occurrence of the substring. You can get that with the `rindex` function, which starts scanning from the end of the string. In this example, you can find the last slash, which turns out to be at position 4 in the string, still counting from the left, just like `index`:

```
my $last_slash = rindex("/etc/passwd", "/"); # value is 4
```

The `rindex` function also has an optional third parameter, but in this case, it effectively gives the *maximum* permitted return value:

```
my $fred = "Yabba dabba doo!";

my $where1 = rindex($fred, "abba"); # $where1 gets 7
my $where2 = rindex($fred, "abba", $where1 - 1); # $where2 gets
1
my $where3 = rindex($fred, "abba", $where2 - 1); # $where3 gets
-1
```

And here is its loop form. In this example, instead of starting at `-1`, we start at the position one beyond the last position. The length of the string is one greater than the zero-based last position:

```
use v5.10;

my $fred = "Yabba dabba doo!";

my @where = ();
my $where = length $fred;
while( 1 ) {
    $where = rindex($fred, "abba", $where - 1 );
    last if $where == -1;
    push @where, $where;
}
say "Positions are @where";
```

Manipulating a Substring with `substr`

The `substr` function works with only a part of a larger string. It looks like this:

```
my $part = substr($string, $initial_position, $length);
```

It takes three arguments: a string value, a zero-based initial position (such as the return value of `index`), and a length for the substring. The return

value is the substring:

```
my $mineral = substr("Fred J. Flintstone", 8, 5); # gets "Flint"
my $rock = substr "Fred J. Flintstone", 13, 1000; # gets "stone"
```

The third argument to `substr` is the length of the substring you want. It's always going to be the length no matter how badly we want it to be the end position.

As you may have noticed in the previous example, if the requested length (1000 characters, in this case) would go past the end of the string, Perl won't complain, but you get a shorter string than you might have expected. But if you want to be sure to go to the end of the string, however long or short it may be, just omit that third parameter (the length), like this:

```
my $pebble = substr "Fred J. Flintstone", 13; # gets "stone"
```

The initial position of the substring in the larger string can be negative, counting from the end of the string (that is, position `-1` is the last character). In this example, position `-3` is three characters from the end of the string, which is the location of the letter `i`:

```
my $out = substr("some very long string", -3, 2); # $out gets
"in"
```

As you might expect, `index` and `substr` work well together. In this example, you can extract a substring that starts at the location of the letter `l`:

```
my $long = "some very very long string";
my $right = substr($long, index($long, "l") );
```

Now here's something really cool—you can change the selected portion of the string if the string is a variable:

```
my $string = "Hello, world!";
substr($string, 0, 5) = "Goodbye"; # "Goodbye, world!"
```

As you can see, the assigned (sub)string doesn't have to be the same length as the substring it's replacing. The string's length is adjusted to fit.

If you give it a length of 0, you can insert text without removing anything:

```
substr($string, 9, 0) = "cruel ";    # "Goodbye, cruel world!";
```

Or if that wasn't cool enough to impress you, you could use the binding operator (`=~`) to restrict an operation to work with just part of a string. This example replaces `fred` with `barney` wherever possible within just the last 20 characters of a string:

```
substr($string, -20) =~ s/fred/barney/g;
```

Much of the work that you do with `substr` and `index` you could also do with regular expressions. Use those where they're appropriate. But `substr` and `index` can often be faster, since they don't have the overhead of the regular expression engine: they're never case-insensitive, they have no metacharacters to worry about, and they don't set any of the capture variables.

Besides assigning to the `substr` function (which looks a little weird at first glance, perhaps), you can also use `substr` in a slightly more traditional manner with the four-argument version, in which the fourth argument is the replacement substring:

```
my $previous_value = substr($string, 0, 5, "Goodbye");
```

The previous value comes back as the return value, although as always, you can use this function in a void context to simply discard it.

Formatting Data with `sprintf`

The `sprintf` function takes the same arguments as `printf` (except for the optional filehandle, of course), but it returns the requested string instead of printing it. This is handy if you want to store a formatted string in a

variable for later use, or if you want more control over the result than `printf` alone would provide:

```
my $date_tag = sprintf
    "%4d/%02d/%02d %2d:%02d:%02d",
    $yr, $mo, $da, $h, $m, $s;
```

In that example, `$date_tag` gets something like `"2038/01/19 3:00:08"`. The format string (the first argument to `sprintf`) used a leading zero on the format width number, which we didn't mention when we talked about `printf` formats in [Chapter 5](#). The leading zero on the format number means to use leading zeros as needed to make the number as wide as requested. Without a leading zero in the formats, the resulting date-and-time string would have unwanted leading spaces instead of zeros, looking like `"2038/ 1/19 3: 0: 8"`.

Using `sprintf` with “Money Numbers”

One popular use for `sprintf` is when you want to format a number with a certain number of places after the decimal point, such as when you want to show an amount of money as `2.50` and not `2.5`—and certainly not as `2.49997`! That's easy to accomplish with the `"%.2f"` format:

```
my $money = sprintf "%.2f", 2.49997;
```

The full implications of rounding are numerous and subtle, but in most cases you should keep numbers in memory with all of the available accuracy, rounding off only for output.

If you have a “money number” that may be large enough to need commas to show its size, you might find it handy to use a subroutine like this one:

```
sub big_money {
    my $number = sprintf "%.2f", shift @_;
    # Add one comma each time through the do-nothing loop
    1 while $number =~ s/^(-?\d+) (\d\d\d)/$1,$2/;
    # Put the dollar sign in the right place
```

```
$number =~ s/^(-?)/$1\$/;  
$number;  
}
```

This subroutine uses some techniques you haven't seen yet, but they logically follow from what we've shown you. The first line of the subroutine formats the first (and only) parameter to have exactly two digits after the decimal point. That is, if the parameter were the number 12345678.9, now your `$number` is the string "12345678.90".

The next line of code uses a `while` modifier. As we mentioned when we covered that modifier in [Chapter 10](#), that can always be rewritten as a traditional `while` loop:

```
while ($number =~ s/^(-?\d+)(\d\d\d)/$1,$2/) {  
    1;  
}
```

NOTE

In this example, we hardcoded the comma as the thousands separator. The `Number::Format` and `CLDR::Number` modules are more interesting to people who really care about these things.

What does that say to do? It says that as long as the substitution returns a true value (signifying success), the loop body should run. But the loop body does nothing! That's OK with Perl, but it tells us that the purpose of that statement is to do the conditional expression (the substitution) rather than the useless loop body. The value 1 is traditionally used as this kind of a placeholder, although any other value would be equally useful. This works just as well as the loop from before:

```
'keep looping' while $number =~ s/^(-?\d+)(\d\d\d)/$1,$2/;
```

So, now you know that the substitution is the real purpose of the loop. But what is the substitution doing? Remember that `$number` is some string like "12345678.90" at this point. The pattern will match the first part of

the string, but it can't get past the decimal point. (Do you see why it can't?) Memory \$1 will get "12345", and \$2 will get "678", so the substitution will make \$number into "12345, 678.90" (remember, it couldn't match the decimal point, so the last part of the string is left untouched).

Do you see what the dash is doing near the start of that pattern? (Hint: the dash is allowed at only one place in the string.) We'll tell you at the end of this section, in case you haven't figured it out.

You're not done with that substitution statement yet. Since the substitution succeeded, the do-nothing loop goes back to try again. This time, the pattern can't match anything from the comma onward, so \$number becomes "12, 345, 678.90". The substitution thus adds a comma to the number each time through the loop.

Speaking of the loop, it's still not done. Since the previous substitution was a success, you're back around the loop to try again. But this time, the pattern can't match at all, since it has to match at least four digits at the start of the string, so now that is the end of the loop.

Why couldn't you have simply used the /g modifier to do a "global" search-and-replace, to save the trouble and confusion of the 1 while? You couldn't use that because you're working backward from the decimal point rather than forward from the start of the string. You can't put the commas in a number like this simply with the s///g substitution alone. So, did you figure out the dash? It allows a possible minus sign at the start of the string. The next line of code makes the same allowance, putting the dollar sign in the right place so that \$number is something like "\$12, 345, 678.90", or perhaps "-\$12, 345, 678.90" if it's negative. Note that the dollar sign isn't necessarily the first character in the string, or that line would be a lot simpler. Finally, the last line of code returns your nicely formatted "money number," which you can print in the annual report.

Advanced Sorting

In [Chapter 3](#), we showed that you could sort a list in ascending order by using the built-in `sort` operator. What if you want a numeric sort? Or a case-insensitive sort? Or maybe you want to sort items according to information stored in a hash. Well, Perl lets you sort a list in whatever order you'd need; you'll see all of those examples by the end of the chapter.

You'll tell Perl what order you want by making a *sort-definition subroutine*, or *sort subroutine* for short. Now, when you first hear the term “sort subroutine,” if you've been through any computer science courses, visions of bubble sort and shell sort and quick sort race through your head, and you say, “No, never again!” Don't worry; it's not that bad. In fact, it's pretty simple. Perl already knows how to sort a list of items; it merely doesn't know which order you want. So the sort-definition subroutine simply tells it the order.

Why is this necessary? Well, if you think about it, sorting is putting a bunch of things in order by comparing them all. Since you can't compare them all at once, you need to compare two at a time, eventually using what you find out about each pair's order to put the whole kit and caboodle in line. Perl already understands all of those steps *except* for the part about how you'd like to compare the items, so that's all you have to write.

This means that the sort subroutine doesn't need to sort many items after all. It merely has to be able to compare two items. If it can put two items in the proper order, Perl will be able to tell (by repeatedly consulting the sort subroutine) what order you want for your data.

The sort subroutine is defined like an ordinary subroutine (well, almost). This routine will be called repeatedly, each time checking on a pair of elements from the list you're sorting.

Now, if you were writing a subroutine that's expecting to get two parameters that need sorting, you might write something like this to start:

```
sub any_sort_sub {      # It doesn't really work this way
    my($a, $b) = @_;    # Get and name the two parameters
    # start comparing $a and $b here
```

```
    ...  
}
```

But you're going to call that sort subroutine again and again, often hundreds or thousands of times. Declaring the variables `$a` and `$b` and assigning them values at the top of the subroutine will take just a little time, but multiply that by the thousands of times you will call the routine and you can see that it contributes significantly to the overall execution speed.

You don't do it like that. (In fact, if you did it that way, it wouldn't work.) Instead, it is as if Perl has done this for you, before your subroutine's code has even started. You'll really write a sort subroutine without that first line; both `$a` and `$b` have been assigned for you. When the sort subroutine starts running, `$a` and `$b` are two elements from the original list.

The subroutine returns a coded value describing how the elements compare (like C's `qsort(3)` does, but it's Perl's own internal sort implementation). If `$a` should appear before `$b` in the final list, the sort subroutine returns `-1` to say so. If `$b` should appear before `$a`, it returns `1`.

If the order of `$a` and `$b` doesn't matter, the subroutine returns `0`. Why would it not matter? Perhaps you're doing a case-insensitive sort and the two strings are `fred` and `Fred`. Or perhaps you're doing a numeric sort and the two numbers are equal.

You could now write a numeric sort subroutine like this:

```
sub by_number {  
    # a sort subroutine, expect $a and $b  
    if ($a < $b) { -1 } elsif ($a > $b) { 1 } else { 0 }  
}
```

To use the sort subroutine, just put its name (without an ampersand) between the keyword `sort` and the list you're sorting. This example puts a numerically sorted list of numbers into `@result`:

```
my @result = sort by_number @some_numbers;
```

You can call this subroutine `by_number` to describe how it sorts. But more importantly, you can read the line of code that uses it with `sort` as saying “sort by number,” as you would in English. Many people start their sort-subroutine names with `by_` to describe how they sort. Or you could have called this one `numerically` for a similar reason, but that’s more typing and more chance to mess up something.

Notice that you don’t have to do anything in the `sort` subroutine to declare `$a` and `$b` and set their values—and if you did, the subroutine wouldn’t work right. We just let Perl set up `$a` and `$b` for us, so all you need to write is the comparison.

In fact, you can make it even simpler (and more efficient). Since this kind of three-way comparison is frequent, Perl has a convenient shortcut to use to write it. In this case, you use the spaceship operator (`<=>`). This operator compares two numbers and returns `-1`, `0`, or `1` as needed to sort them numerically. So you could write that `sort` subroutine better, like this:

```
sub by_number { $a <=> $b }
```

Since the spaceship compares numbers, you may have guessed that there’s a corresponding three-way string-comparison operator: `cmp`. These two are easy to remember and keep straight. The spaceship has a family resemblance to the numeric comparison operators like `>=`, but it’s three characters long instead of two because it has three possible return values instead of two. And `cmp` has a family resemblance to the string comparison operators like `ge`, but it’s three characters long instead of two because it *also* has three possible return values instead of two. Of course, `cmp` by itself provides the same order as the default `sort`. You’d never need to write this subroutine, which yields merely the default sort order:

```
sub by_code_point { $a cmp $b }

my @strings = sort by_code_point @any_strings;
```


But you can use `cmp` to build a more complex sort order, like a case-insensitive sort:

```
sub case_insensitive { "\F$a" cmp "\F$b" }
```

In this case, you’re comparing the string from `$a` (case-folded) against the string from `$b` (case-folded), giving a case-insensitive sort order.

But remember that Unicode has the concept of canonical and compatible equivalence, which we cover in [Appendix C](#). To sort equivalent forms next to each other, you need to sort the decomposed form. If you are dealing with Unicode strings, this is probably what you want most of the time:

```
use Unicode::Normalize;

sub equivalents { NFKD($a) cmp NFKD($b) }
```

Note that you’re not modifying the elements themselves in any of these; you’re merely using their values. That’s actually important: for efficiency reasons, `$a` and `$b` aren’t copies of the data items. They’re actually new, temporary aliases for elements of the original list, so if you change them, you mangle the original data. Don’t do that—it’s neither supported nor recommended.

When your sort subroutine is as simple as the ones you see here (and most of the time, it is), you can make the code even simpler yet, by replacing the name of the sort routine with the entire sort routine “inline,” like so:

```
my @numbers = sort { $a <=> $b } @some_numbers;
```

In fact, in modern Perl, you’ll hardly ever see a separate sort subroutine; you’ll frequently find sort routines written inline as we’ve done here.

Suppose you want to sort in descending numeric order. That’s easy enough to do with the help of `reverse`:

```
my @descending = reverse sort { $a <=> $b } @some_numbers;
```

But here's a neat trick. The comparison operators (`<=>` and `cmp`) are very nearsighted; that is, they can't see which operand is `$a` and which is `$b`, but only which *value* is on the left and which is on the right. So if `$a` and `$b` were to swap places, the comparison operator would get the results backward every time. That means that this is another way to get a reversed numeric sort:

```
my @descending = sort { $b <=> $a } @some_numbers;
```

You can (with a little practice) read this at a glance. It's a descending-order comparison (because `$b` comes before `$a`, which is descending order), and it's a numeric comparison (because it uses the spaceship instead of `cmp`). So it is sorting numbers in reverse order. (In modern Perl versions, it doesn't matter much which one of those you do, because `reverse` is recognized as a modifier to `sort`, and special shortcuts are taken to avoid sorting it one way just to have to turn it around the other way.)

Sorting a Hash by Value

Once you've been sorting lists happily for a while, you'll run into a situation where you want to sort a hash by value. For example, three of our characters went out bowling last night, and you have their bowling scores in the following hash. You want to be able to print out the list in the proper order, with the game winner at the top, so you have to sort the hash by score:

```
my %score = ("barney" => 195, "fred" => 205, "dino" => 30);
my @winners = sort by_score keys %score;
```

Of course, you aren't really going to be able to sort the hash by score; that's just a verbal shortcut. You can't sort a hash! But when you used `sort` with hashes before now, you sorted the keys of the hash (in code point order). Now, you're still going to sort the keys of the hash, but the order is now defined by their corresponding values from the hash. In this case, the result

should be a list of our three characters' names, in order according to their bowling scores.

Writing this sort subroutine is fairly easy. What you want is to use a numeric comparison on the scores rather than the names. That is, instead of comparing `$a` and `$b` (the players' names), you want to compare `$score{$a}` and `$score{$b}` (their scores). If you think of it that way, it almost writes itself, as in:

```
sub by_score { $score{$b} <=> $score{$a} }
```

Step through this to see how it works. Imagine that the first time it's called, Perl has set `$a` to `barney` and `$b` to `fred`. So the comparison is `$score{"fred"} <=> $score{"barney"}`, which (as you can see by consulting the hash) is `205 <=> 195`. Remember, now, the spaceship is nearsighted, so when it sees 205 before 195, it says, in effect: "No, that's not the right numeric order; `$b` should come before `$a`." So it tells Perl that `fred` should come before `barney`.

Maybe the next time the routine is called, `$a` is `barney` again but `$b` is now `dino`. The nearsighted numeric comparison sees `30 <=> 195` this time, so it reports that they're in the right order; `$a` does indeed sort in front of `$b`. That is, `barney` comes before `dino`. At this point, Perl has enough information to put the list in order: `fred` is the winner, then `barney` in second place, then `dino`.

Why did the comparison use the `$score{$b}` before the `$score{$a}`, instead of the other way around? That's because you want bowling scores arranged in *descending* order, from the highest score of the winner down. So you can (again, after a little practice) read this one at sight as well: `$score{$b} <=> $score{$a}` means to sort according to the scores, in reversed numeric order.

Sorting by Multiple Keys

We forgot to mention that there was a fourth player bowling last night with the other three, so the hash really looked like this:

```
my %score = (  
    "barney" => 195, "fred" => 205,  
    "dino" => 30, "bamm-bamm" => 195,  
);
```

Now, as you can see, bamm-bamm has the same score as barney. So which one will be first in the sorted list of players? There's no telling, because the comparison operator (seeing the same score on both sides) will have to return zero when checking those two.

Maybe that doesn't matter, but you generally prefer to have a well-defined sort. If several players have the same score, you want them to be together in the list, of course. But within that group, the names should be in code point order. How can you write the sort subroutine to say that? Again, this turns out to be pretty easy:

```
my @winners = sort by_score_and_name keys %score;  
  
sub by_score_and_name {  
    $score{$b} <=> $score{$a} # by descending numeric score  
    or  
    $a cmp $b                # code point order by name  
}
```

How does this work? Well, if the spaceship sees two different scores, that's the comparison you want to use. It returns `-1` or `1`, a true value, so the low-precedence short-circuit `or` will mean the rest of the expression will be skipped, and the comparison you want is returned. (Remember, the short-circuit `or` returns the last expression evaluated.) But if the spaceship sees two identical scores, it returns `0`, a false value, and thus the `cmp` operator gets its turn at bat, returning an appropriate ordering value considering the keys as strings. That is, if the scores are the same, the string-order comparison breaks the tie.

You know that when you use the `by_score_and_name` sort subroutine like this, it will never return 0, because no two hash keys are equal. So you know that the sort order is always well defined; that is, you know that the result today will be the same as the result with the same data tomorrow.

There's no reason that your sort subroutine has to be limited to two levels of sorting, of course. Here the Bedrock Library program puts a list of patron ID numbers in order according to a five-level sort. This example sorts according to the amount of each patron's outstanding fines (as calculated by a subroutine `&fines`, not shown here), the number of items they currently have checked out (from `%items`), their name (in order by family name, then by personal name, both from hashes), and finally by the patron's ID number, in case everything else is the same:

```
@patron_IDs = sort {
    &fines($b) <=> &fines($a) or
    $items{$b} <=> $items{$a} or
    $family_name{$a} cmp $family_name{$b} or
    $personal_name{$a} cmp $personal_name{$b} or
    $a <=> $b
} @patron_IDs;
```

Exercises

See “[Answers to Chapter 14 Exercises](#)” for answers to these exercises:

1. [10] Write a program to read in a list of numbers and sort them numerically, printing out the resulting list in a right-justified column. Try it out on this sample data:

```
17 1000 04 1.50 3.14159 -10 1.5 4 2001 90210 666
```

2. [15] Make a program that will print the following hash's data sorted in case-insensitive alphabetical order by last name. When the last names are the same, sort those by first name (again, without regard for case). That is, the first name in the output should be Fred's, while the last one should be Betty's. All of the

people with the same family name should be grouped together. Don't alter the data. The names should be printed with the same capitalization as shown here:

```
my %last_name = qw{
    fred flintstone Wilma Flintstone Barney Rubble
    betty rubble Bamm-Bamm Rubble PEBBLES FLINTSTONE
};
```

3. [15] Make a program that looks through a given string for every occurrence of a given substring, printing out the positions where the substring is found. For example, given the input string "This is a test." and the substring "is", it should report positions 2 and 5. If the substring were "a", it should report 8. What does it report if the substring is "t"?

Chapter 15. Process Management

One of the best parts of being a programmer is launching someone else's code so that you don't have to write it yourself. It's time to learn how to manage your children—child processes, that is—by launching other programs directly from Perl.

And like everything else in Perl, There's More Than One Way To Do It, with lots of overlap, variations, and special features. So, if you don't like the first way, just read on for another page or two for a solution more to your liking.

Perl is very portable; most of the rest of this book doesn't need many notes saying that it works this way in Unix systems and that way in Windows and some other way on VMS. But when you're starting other programs on your machine, different programs are available on a Macintosh than what you'll likely find on an old Cray (which used to be a “super” computer). The examples in this chapter are primarily Unix based; if you have a non-Unix system, you can expect to see some differences.

The system Function

The simplest way to launch a child process in Perl to run a program is with the `system` function. For example, to invoke the Unix *date* command from within Perl, you tell `system` that's the program you want to run:

```
system 'date';
```

These commands depend on your system, what it provides, and how it implements those commands. They aren't Perl, but something Perl asks the system to do for your program. The same Unix command might have

different calling conventions and options on different versions of that operating system.

If you are using Windows, that code will show you the date but also prompt you to enter a new date. Your program will wait for you to enter a new date. You probably want the `/T` switch to suppress that:

```
system 'date /T';
```

You run that from the *parent* process. When it runs, the `system` command creates an identical copy of your Perl program, called the *child* process. The child process immediately changes itself into the command that you want to run, such as *date*, sharing Perl's standard input, standard output, and standard error. This means that the normal short date-and-time string generated by *date* ends up wherever Perl's `STDOUT` was already going.

The parameter to the `system` function is generally whatever you normally type at the shell. So, if it were a more complicated command, like *ls -l \$HOME* to list the contents of your home directory, you could put all that into the parameter:

```
system 'ls -l $HOME';
```

That `$HOME` is a shell variable that knows the path to your home directory. It's not a Perl variable and you don't want to interpolate it. If you had it in double quotes, you'd have to escape the `$` to prevent the interpolation:

```
system "ls -l \"$HOME\"";
```

On Windows, the same task uses the *dir* command. The `%` signs belong to the command, not a Perl variable. But hashes don't interpolate in double-quoted strings, so you don't need to escape them:

```
system "cmd /c dir %userprofile%"
```


NOTE

If you have Cygwin or MinGW installed, some of the Windows command shell commands may run something different than what you expect. Using `cmd /c` ensures that you get the Windows version.

Now, the normal Unix *date* command is output-only, but let's say it's a chatty command, asking first "for which time zone do you want the time?", or that the Windows version prompts you for the new date. That message ends up on standard output and the program listens on standard input (inherited from Perl's `STDIN`) for the response. You see the question, and type in the answer (like "Zimbabwe time"), and then *date* will finish its duty.

While the child process is running, Perl patiently waits for it to finish. So if the *date* command takes 37 seconds, Perl pauses for those 37 seconds. You can use the shell's facility to launch a background process, however:

```
system "long_running_command with parameters &;"
```

Here, the shell gets launched, which then notices the ampersand at the end of the command line, causing the shell to put `long_running_command` into the background. And then the shell exits rather quickly; Perl notices this and moves on. In this case, the `long_running_command` is really a *grandchild* of the Perl process, to which Perl really has no direct access or knowledge.

Windows doesn't have a backgrounding mechanism, but *start* can run the command without your program waiting for it:

```
system 'start /B long_running_command with parameters'
```

When a command is "simple enough," no shell gets involved. So for the *date* and *ls* commands earlier, Perl directly launched your requested command, which searches the inherited `PATH` to find the command, if necessary. But if there's anything weird in the string (such as shell

metacharacters like the dollar sign, semicolon, or vertical bar), Perl invokes the standard Bourne Shell (*/bin/sh*) in Unix or the shell set in the `PERL5SHELL` environment variable in Windows (by default, that's *cmd /x/d/c*).

NOTE

The `PATH` is the list of directories your system searches to find programs. You can change `PATH` by adjusting `$ENV{ 'PATH' }` at any time.

For example, you can write an entire little shell script in the argument. This one prints the contents of all the (nonhidden) files in the current directory:

```
system 'for i in *; do echo == $i ==; cat $i; done';
```

Here, again, you're using single quotes because the dollar signs are for the shell and not for Perl. Double quotes would allow Perl to interpolate `$i` to its current Perl value and not let the shell expand it to its own value.

On Windows you don't have those interpolation issues. The `/R` works recursively, so you might end up with a long list of files:

```
system 'for /R %i in (*) DO echo %i & type %i'
```

Note that your ability to do this doesn't mean it's wise for you to do this. You know it's possible, but often there's a pure Perl solution that will do the same thing. On the other hand, Perl is a glue language meant to work in the ugly spaces between programs that need to coordinate with each other.

Avoiding the Shell

The system operator may also be invoked with more than one argument, in which case a shell doesn't get involved, no matter how complicated the text:

```
my $starfile = 'something*wicked.tar';
my @dirs = qw(fred|flintstone <barney&rubble> betty );
system 'tar', 'cvf', $starfile, @dirs;
```

NOTE

`system` can use an indirect object, such as `system { 'fred' } 'barney';`, which runs the program `barney`, but lies to it so that it thinks it's called `'fred'`. See the [perlsec documentation](#) or *Mastering Perl*'s security chapter for more details.

In this case, the first parameter (`'tar'` here) gives the name of a command found in the normal `PATH`-searching way, while Perl passes the remaining arguments one by one, directly to that command. Even if the arguments have shell-significant characters, such as the name in `$starfile` or the directory names in `@dirs`, the shell never gets a chance to mangle the string. That `tar` command will get precisely five parameters. Compare that with this security problem:

```
system "tar cvf $starfile @dirs"; # Oops!
```

Here, you've now piped a bunch of stuff into a *flintstone* command, put it into the background, and opened *betty* for output. That's a relatively tame effect, but what if `@dirs` was something more interesting, such as:

```
my @dirs = qw( ; rm -rf / );
```

It doesn't matter that `@dirs` is a list, because Perl simply interpolates it into the single string to pass to `system`.

And that's a bit scary, especially if those variables are from user input—such as from a web form or something. So if you *can* arrange things so that you can use the multiple-argument version of `system`, you probably should use that way to launch your subprocess. You'll have to give up the ability to have the shell do the work for you to set up I/O redirection,

background processes, and the like, though. There's no such thing as a free lunch.

Note that redundantly, a single-argument invocation of `system` is nearly equivalent to the proper multiple-argument version of `system`:

```
system $command_line;  
system '/bin/sh', '-c', $command_line;
```

But nobody writes the latter since that's what Perl does already. If you want things processed by a different shell, like the C-shell, you can specify that:

```
system '/bin/csh', '-fc', $command_line;
```

This is also handy for handling whitespace in filenames since the shell doesn't step in to break up the arguments. This command sees exactly one filename:

```
system 'touch', 'name with spaces.txt';
```

NOTE

See *Mastering Perl* for a longer discussion of the security features of the list form of `system`. The [perlsec documentation](#) comes in handy too.

On Windows, you can set the `$ENV{PERL5SHELL}` value to be the shell that you want. You'll see environment variables in the next section, so keep reading.

The return value of the `system` operator is based on the exit status of the child command:

```
unless (system 'date') {  
    # Return was zero, meaning success  
    print "We gave you a date, OK!\n";  
}
```

An exit value of 0 usually means that everything is OK, and a nonzero exit value usually indicates that something went wrong. This is part of the “0 but true” notion that the value of zero is a good thing. This is backward from the normal “true is good—false is bad” strategy for most of the operators, so to write a typical “do this or die” style, we’ll need to flip false and true. The easiest way is to simply prefix the `system` operator with a bang (the logical-not operator):

```
!system 'rm -rf files_to_delete' or die 'something went wrong';
```

In this case, including `$!` in the error message is not appropriate, because the failure is most likely somewhere within the experience of the external `rm` command, and it’s not a `system`-related error within Perl that `$!` can reveal.

Don’t rely on this behavior, though. It’s up to each command to decide what it wants to return. Some values may be nonzero but also indicate success. If that’s the case, you need to inspect the return value more closely.

The `system` return value is two octets. The “high” octet has the exit value of the program. If you want that, you need to shift the bits down eight bits (remember the bit operators from [Chapter 12](#)):

```
my $return_value    = system( ... );
my $child_exit_code = $return_value >> 8;
```

The “low” octet combines several things. The highest bit notes if a core dump happened. The hexadecimal and binary representations (recall them from [Chapter 2](#)) can help mask out the parts you don’t want:

```
my $low_octet      = $return_value & 0xFF; # mask out high octet
my $dumped_core    = $low_octet & 0b1_0000000; # 128
my $signal_number  = $low_octet & 0b0111_1111; # 0x7f, or 127
```

Since Windows doesn’t have signals, the bits in these positions may have other meanings.

NOTE

Your system may have a more specific error message in the variable `$^E` or `${^CHILD_ERROR_NATIVE}`. See [perlrun](#) and the `POSIX` module (especially the `W*` macros to decode signals).

The Environment Variables

When you're starting another process (with any of the methods we show here), you may need to set up its environment in one way or another. As we mentioned earlier, you could start the process with a certain working directory, which it inherits from your process. Another common configuration detail is the environment variables.

One of the best-known environment variables is `PATH`. (If you've never heard of it, you probably haven't used a system that has environment variables.) On Unix and similar systems, `PATH` is a colon-separated list of directories that may hold programs. When you type a command like *rm fred*, the system will look for the *rm* command in that list of directories, in order. Perl (or your system) will use `PATH` whenever it needs to find the program to run. If the program in turn runs other programs, those may also be found along the `PATH`. (Of course, if you give a complete name for a command, such as */bin/echo*, there's no need to search `PATH`. But that's generally much less convenient.)

In Perl, the environment variables are available via the special `%ENV` hash; each key in this hash represents one environment variable. At the start of your program's execution, `%ENV` holds values it has inherited from its parent process (generally the shell). Modifying this hash changes the environment variables, which will then be inherited by new processes and possibly used by Perl as well. For example, suppose you wished to run the system's *make* utility (which typically runs other programs), and you want to use a private directory as the first place to look for commands (including *make* itself). And let's say that you don't want the `IFS` environment

variable to be set when you run the command, because that might cause *make* or some subcommand to do the wrong thing. Here we go:

```
$ENV{'PATH'} = "/home/rootbeer/bin:$ENV{'PATH'}";  
delete $ENV{'IFS'};  
my $make_result = system 'make';
```

Different systems construct their paths differently. Unix uses colons, but Windows uses semicolons, for instance. This is your constant headache of working with external programs. You have to know a lot that isn't Perl. But Perl knows about the system it runs on, and you can find out what it knows with the `Config` module through its `%Config` variable. Instead of assuming the `PATH` separator as you did in the previous example, you could use `join` with a glue string you get from `%Config`:

```
use Config;  
$ENV{'PATH'} = join $Config{'path_sep'},  
    '/home/rootbeer/bin', $ENV{'PATH'};
```

Newly created processes will generally inherit from their parent the environment variables, the current working directory, the standard input, output, and error streams, and a few more esoteric items. See the documentation about programming on your system for more details. (But on most systems, your program can't change the environment for the shell or other parent process that started it.)

The `exec` Function

Everything we've just said about `system` syntax and semantics is also true about the `exec` function, except for one (very important) thing. The `system` function creates a child process, which then scurries off to perform the requested action while Perl naps. The `exec` function causes the Perl process *itself* to perform the requested action. Think of it as more like a "goto" than a subroutine call.

For example, suppose you wanted to run the *bedrock* command in the */tmp* directory, passing it arguments of *-o args1* followed by whatever arguments your own program was invoked with. That'd look like this:

```
chdir '/tmp' or die "Cannot chdir /tmp: $!";
exec 'bedrock', '-o', 'args1', @ARGV;
```

When you reach the `exec` operation, Perl locates *bedrock* and “jumps into it.” At that point, there is no Perl process anymore, even though it's the same process, having performed the Unix `exec` system call (or equivalent). The process ID remains the same, but it's now just the process running the *bedrock* command. When *bedrock* finishes, there's no Perl to come back to.

Why is this useful? Sometimes you want to use Perl to set up the environment for a program. You can affect environment variables, change the current working directory, and change the default filehandles:

```
$ENV{PATH} = '/bin:/usr/bin';
$ENV{DEBUG} = 1;
$ENV{ROCK} = 'granite';

chdir '/Users/fred';
open STDOUT, '>', '/tmp/granite.out';

exec 'bedrock';
```

If you use `system` instead of `exec`, you have a Perl program just standing around tapping its toes, waiting for the other program to complete just so Perl could finally immediately exit as well, and that wastes a resource.

Having said that, it's actually quite rare to use `exec`, except in combination with `fork` (which you'll see later). If you are puzzling over `system` versus `exec`, just pick `system`, and nearly all of the time you'll be just fine.

Because Perl is no longer in control once the requested command has started, it doesn't make any sense to have any Perl code following the

`exec`, except for handling the error when the requested command cannot be started:

```
exec 'date';  
die "date couldn't run: $!";
```

Using Backquotes to Capture Output

With both `system` and `exec`, the output of the launched command ends up wherever Perl's standard output is going. Sometimes it's interesting to capture that output as a string value to perform further processing. And that's done simply by creating a string using backquotes instead of single or double quotes:

```
my $now = `date`;           # grab the output of date  
print "The time is now $now"; # newline already present
```

Normally, this *date* command spits out a string approximately 30 characters long to its standard output, giving the current date and time followed by a newline. When you've placed *date* between backquotes, Perl executes the *date* command, arranging to capture its standard output as a string value, and in this case assigning it to the `$now` variable.

This is very similar to the Unix shell's meaning for backquotes. However, the shell also performs the additional job of ripping off the final end-of-line to make it easier to use the value as part of other things. Perl is honest; it gives the real output. To get the same result in Perl, you can simply add an additional `chomp` operation on the result:

```
chomp(my $no_newline_now = `date`);  
print "A moment ago, it was $no_newline_now, I think.\n";
```

The value between backquotes is just like the single-argument form of `system` and is interpreted as a double-quoted string, meaning that backslash-escapes and variables are expanded appropriately. For example,

to fetch the Perl documentation on a list of Perl functions, we might invoke the *perldoc* command repeatedly, each time with a different argument:

```
my @functions = qw{ int rand sleep length hex eof not exit sqrt
umask };
my %about;

foreach (@functions) {
    $about{$_} = `perldoc -t -f $_`;
}
```

Note that `$_` has a different value for each invocation, letting you grab the output of a different command that varies in only one of its parameters.

Also note that if you haven't seen some of these functions yet, it might be useful to look them up in the documentation to see what they do!

Instead of the backquotes, you can use the generalized quoting operator, `qx()`, that does the same thing:

```
foreach (@functions) {
    $about{$_} = qx(perldoc -t -f $_);
}
```

As with the other generalized quotes, you mainly use this when the stuff inside the quotes also contains the default delimiter. If you want to have a literal backquote in your command, you can use the `qx()` mechanism to avoid the hassle of escaping the offending character. There's another benefit to generalized quoting: if you use the single quote as the delimiter, the quoting does not interpolate anything. If you want to use the shell's process ID variable, `$$`, instead of Perl's, you use `qx'` to avoid the interpolation:

```
my $output = qx'echo $$';
```

At the risk of actually introducing the behavior by demonstrating how *not* to do it, we'd also like to suggest that you avoid using backquotes in a place where the value isn't being captured. For example:

```
print "Starting the frobnitzigator:\n";  
`frobnitz -enable`; # no need to do this if you ignore the string  
print "Done!\n";
```

The problem is that Perl has to work a bit harder to capture the output of this command, even if you don't use it. This is known as *void context* and you should generally avoid asking Perl to do work when you won't use the result. You also lose the option to use multiple arguments to `system` to precisely control the argument list. So from both a security standpoint and an efficiency viewpoint, just use `system` instead, please.

Standard error of a backquoted command goes to the same place as Perl's current standard error output. If the command spits out error messages to the default standard error, you'll probably see them on the terminal, which could be confusing to the user who hasn't personally invoked the *frobnitz* command but still sees its errors. If you want to capture error messages with standard output, you can use the shell's normal "merge standard error to the current standard output," which is spelled `2>&1` in the normal Unix and Windows shells:

```
my $output_with_errors = `frobnitz -enable 2>&1`;
```

Note that this will intermingle the standard error output with the standard output, much as it appears on the terminal (although possibly in a slightly different sequence because of buffering). If you need the output and the error output separated, there are many more flexible solutions, such as `IPC::Open3` in the standard Perl library, or writing your own forking code, as you will see later. Similarly, standard input is inherited from Perl's current standard input. Most commands you typically use with backquotes do not read standard input, so that's rarely a problem. However, let's say the *date* command asked which time zone (as we imagined earlier). That'll be a problem because the prompt for "which time zone" will be sent to standard output, which is being captured as part of the value, and then the *date* command will start trying to read from standard input. But since the user has never seen the prompt, they don't know they should be typing anything! Pretty soon, the user calls you up and tells you your program is stuck.

So, stay away from commands that read standard input. If you're not sure whether something reads from standard input, add a redirection from */dev/null* for input, like this for Unix:

```
my $result = `some_questionable_command arg arg argh </dev/null`;
```

and like this for Windows:

```
my $result = `some_questionable_command arg arg argh < NUL`;
```

Then the child shell will redirect input from the “null device,” and the questionable grandchild command will, at worst, try to read and immediately get an end-of-file.

NOTE

The `Capture::Tiny` and `IPC::System::Simple` modules can capture the output while handling the system-specific details for you. Install them from CPAN.

Using Backquotes in a List Context

The scalar context use of backquotes returns the captured output as a single long string, even if it looks to you like there are multiple “lines” because it has newlines. Computers don’t care about lines, really. That’s something we care about and tell computers to interpret for us. Those newlines are just another character as far as a computer is concerned. However, using the same backquoted string in a list context yields a list containing one line of output per element.

For example, the Unix *who* command normally spits out a line of text for each current login on the system as follows:

```
merlyn      tty/42      Dec 7   19:41
rootbeer    console     Dec 2   14:15
rootbeer    tty/12       Dec 6   23:00
```

The left column is the username, the middle column is the TTY name (that is, the name of the user's connection to the machine), and the rest of the line is the date and time of login (and possibly remote login information, but not in this example). In a scalar context, we get all that at once, which we would then need to split up on our own:

```
my $who_text = `who`;
my @who_lines = split /\n/, $who_text;
```

But in a list context, we automatically get the data broken up by lines:

```
my @who_lines = `who`;
```

You'll have a number of separate elements in `@who_lines`, each one terminated by a newline. Of course, adding a `chomp` around the outside of that will rip off those newlines, but you can go in a different direction. If you put that as part of the value for a `foreach`, you'll iterate over the lines automatically, placing each one in `$_`:

```
foreach (`who`) {
    my($user, $tty, $date) = /(\S+)\s+(\S+)\s+(.*)/;
    $tts{$user} .= "$tty at $date\n";
}
```

This loop will iterate three times for the sample `who` output. (Your system will probably have more than three active logins at any given time.) Notice that you have a regular expression match, and in the absence of the binding operator (`=~`), it matches against `$_`—which is good, because that's where the data is.

Also notice the regular expression looks for a nonblank word, some whitespace, a nonblank word, some whitespace, and then the rest of the line up to, but not including, the newline (since dot doesn't match newline by default). That's also good, because that's what the data looks like each time in `$_`. That'll make `$1` be `merlyn`, `$2` be `tty/42`, and `$3` be `Dec 7 19:41`, as a successful match on the first time through the loop.

NOTE

Now you can see *why* dot (or `\N`) doesn't match newline by default. It makes it easy to write patterns like this one, in which we don't have to worry about a newline at the end of the string.

However, this regular expression match is in a list context, so you get the list of memories instead of the true/false “did it match” value, as you saw in [Chapter 8](#). So, `$user` ends up being `merlyn`, and so on.

The second statement inside the loop simply stores away the TTY and date information, appending to a (possibly `undef`) value in the hash, because a user might be logged in more than once, as user `rootbeer` was in that example.

External Processes with `IPC::System::Simple`

Running or capturing output from external commands is tricky business, especially since Perl aims to work on so many diverse platforms, each with its own way of doing things. Paul Fenwick's `IPC::System::Simple` module fixes that by providing a simpler interface that hides the complexity of the operating system-specific stuff. It doesn't come with Perl (yet), so you have to get it from CPAN.

There's really not that much to say about this module, because it is truly simple. You can use it to replace the built-in `system` with its own, more robust version:

```
use IPC::System::Simple qw(system);

my $starfile = 'something*wicked.tar';
my @dirs = qw(fred|flintstone <barney&rubble> betty );
system 'tar', 'cvf', $starfile, @dirs;
```

It also provides a `systemx` that never uses the shell, so you should never have the problem of unintended shell actions:

```
systemx 'tar', 'cvf', $starfile, @dirs;
```

If you want to capture the output, you change the `system` or `systemx` to `capture` or `capturex`, both of which work like backquotes (but better):

```
my @output = capturex 'tar', 'cvf', $starfile, @dirs;
```

Paul put in a lot of work to ensure that these subroutines do the right thing under Windows. There's a lot more that this module can do to make your life easier, although we'll refer you to the module documentation for that since some of the fancier features require references, which we don't show you until you read *Intermediate Perl*. If you can use this module, we recommend it over the built-in Perl operators for the same thing.

Processes as Filehandles

So far, you've seen ways to deal with synchronous processes, where Perl stays in charge, launches a command, (usually) waits for it to finish, then possibly grabs its output. But Perl can also launch a child process that stays alive, communicating to Perl on an ongoing basis until the task is complete.

The syntax for launching a concurrent (parallel) child process is to put the command as the “filename” for an `open` call, and either precede or follow the command with a vertical bar, which is the “pipe” character. For that reason, this is often called a *pipelined open*. In the two-argument form, the pipe goes before or after the command that you want to run:

```
open DATE, 'date|' or die "cannot pipe from date: $!";  
open MAIL, '|mail merlyn' or die "cannot pipe to mail: $!";
```

In the first example, with the vertical bar on the right, Perl launches the command with its standard output connected to the `DATE` filehandle opened

for reading, similar to the way that the command *date | your_program* would work from the shell. In the second example, with the vertical bar on the left, Perl connects the command's standard input to the `MAIL` filehandle opened for writing, similar to what happens with the command *your_program | mail merlyn*. In either case, the command continues independently of the Perl process. The `open` fails if Perl can't start the child process. If the command itself does not exist or exits erroneously, Perl will not see this as an error when opening the filehandle, but as an error when closing it. We'll get to that in a moment.

NOTE

If the Perl process exits before the command is complete, a command that's been reading will see end-of-file, while a command that's been writing will get a "broken pipe" error signal on the next write, by default.

The three-argument form is a bit tricky, because for the read filehandle, the pipe character comes after the command. There are special modes for that, though. For the filehandle mode, if you want a read filehandle, you use `-|`, and if you want a write filehandle, you use `|-` to show which side of the pipe you want to place the command:

```
open my $date_fh, '-|', 'date' or die "cannot pipe from date:
$!";
open my $mail_fh, '|-', 'mail merlyn'
    or die "cannot pipe to mail: $!";
```

The pipe `open` can also take more than three arguments. The fourth and subsequent arguments become the arguments to the command, so you can break up that command string to separate the command name from its arguments:

```
open my $mail_fh, '|-', 'mail', 'merlyn'
    or die "cannot pipe to mail: $!";
```


Sadly, the list form of the piped `open` doesn't work in Windows. You'll have to settle for a module to do that for you.

Either way, for all intents and purposes, the rest of the program doesn't know, doesn't care, and would have to work pretty hard to figure out that this is a filehandle opened on a process rather than on a file. So, to get data from a filehandle opened for reading, you read the filehandle normally:

```
my $now = <$date_fh>;
```

And to send data to the mail process (waiting for the body of a message to deliver to `merlyn` on standard input), a simple print-with-a-filehandle will do:

```
print $mail_fh "The time is now $now"; # presume $now ends in  
newline
```

In short, you can pretend that these filehandles are hooked up to magical files, one that contains the output of the *date* command, and one that will automatically be mailed by the *mail* command.

If a process is connected to a filehandle that is open for reading, and then exits, the filehandle returns end-of-file, just like reading up to the end of a normal file. When you close a filehandle open for writing to a process, the process will see end-of-file. So, to finish sending the email, close the handle:

```
close $mail_fh;  
die "mail: nonzero exit of $?" if $?;
```

When closing a filehandle attached to a process, Perl waits for the process to complete so that it can get the process's exit status. The exit status is then available in the `$?` variable (reminiscent of the same variable in the Bourne Shell) and is the same kind of number as the value returned by the `system` function: zero for success, nonzero for failure. Each new exited process overwrites the previous value, though, so save it quickly if you want it.

(The `$?` variable also holds the exit status of the most recent `system` or backquoted command, if you're curious.)

The processes are synchronized just like a pipelined command. If you try to read and no input is available, the process is suspended (without consuming additional CPU time) until the sending program has started speaking again. Similarly, if a writing process gets ahead of the reading process, the writing process is slowed down until the reader starts to catch up. There's a buffer (usually 8 KB or so) in between, so they don't have to stay precisely in lockstep.

Why use processes as filehandles? Well, it's the only easy way to write to a process based on the results of a computation. But if you're just reading, backquotes are often much easier to manage, unless you want to have the results as they come in.

For example, the Unix *find* command locates files based on their attributes, and it can take quite a while if used on a fairly large number of files (such as starting from the root directory). You can put a *find* command inside backquotes, but it's often nicer to see the results as they are found:

```
open my $find_fh, '-|',
    'find', qw( / -atime +90 -size +1000 -print )
    or die "cannot pipe from find: $!";
while (<$find_fh>) {
    chomp;
    printf "%s size %dK last accessed %.2f days ago\n",
        $_, (1023 + -s $_)/1024, -A $_;
}
```

That *find* command looks for all the files that have not been accessed within the past 90 days and that are larger than 1,000 blocks (these are good candidates to move to longer-term storage). While *find* is searching and searching, Perl can wait. As it finds each file, Perl responds to the incoming name and displays some information about that file for further research. Had this been written with backquotes, you would not see any output until the *find* command had completely finished, and it's comforting to see that it's actually doing the job even before it's done.

Getting Down and Dirty with fork

In addition to the high-level interfaces already described, Perl provides nearly direct access to the low-level process management system calls of Unix and some other systems. If you've never done this before, you will probably want to skip this section. While it's a bit much to cover all that stuff in a chapter like this, let's at least look at a quick reimplementaion of this:

```
system 'date';
```

You can do that using the low-level system calls:

```
defined(my $pid = fork) or die "Cannot fork: $!";
unless ($pid) {
    # Child process is here
    exec 'date';
    die "cannot exec date: $!";
}
# Parent process is here
waitpid($pid, 0);
```

NOTE

Windows does not support a native `fork`, but Perl tries to fake it. If you want to do this sort of thing, you can use `Win32::Process` or a similar module for native process management.

Here, you check the return value from `fork`, which is `undef` if it failed. Usually it succeeds, causing two separate processes to continue to the next line, but only the parent process has a nonzero value in `$pid`, so only the child process executes the `exec` function. The parent process skips over that and executes the `waitpid` function, waiting for that particular child to finish (if others finish in the meantime, they are ignored). If that all sounds like gobbledygook, just remember that you can continue to use the `system` function without being laughed at by your friends.

When you go to this extra trouble, you also have full control over creating arbitrary pipes, rearranging filehandles, and noticing your process ID and your parent's process ID (if knowable). But again, that's all a bit complicated for this chapter, so see the details in the [perlipc documentation](#) (and in any good book on application programming for your system) for further information.

Sending and Receiving Signals

A Unix signal is a tiny message sent to a process. It can't say much; it's like a car horn honking. Does that honk you hear mean “look out—the bridge collapsed” or “the light has changed—get going” or “stop driving—you've got a baby on the roof” or “hello, world”? Well, fortunately, Unix signals are a little easier to interpret than that because there's a different one for each of these situations. Well, not *exactly* these situations, but analogous Unix-like ones. For these, the signals are `SIGHUP`, `SIGCONT`, `SIGINT`, and the fake `SIGZERO` (signal number zero).

NOTE

Windows implements a subset of POSIX signals, so much of this might not be true on that system.

Different signals are identified by a name (such as `SIGINT`, meaning “interrupt signal”) and a corresponding small integer (in the range from 1 to 16, 1 to 32, or 1 to 63, depending on your Unix flavor). Programs or the operating system typically send signals to another program when a significant event happens, such as pressing the interrupt character (typically Ctrl-C) on the terminal, which sends a `SIGINT` to all the processes attached to that terminal. Some signals are sent automatically by the system, but they can also come from another process.

You can send signals from your Perl process to another process, but you have to know the target's process ID number. How you figure that out is a

bit complicated, but let's say you know that you want to send a SIGINT to process 4201. That's easy enough if you know that SIGINT corresponds to the number 2:

```
kill 2, 4201 or die "Cannot signal 4201 with SIGINT: $!";
```

It's named "kill" because one of the primary purposes of signals is to stop a process that's gone on long enough. You can also use the string 'INT' in place of the 2, so you don't have to know the number:

```
kill 'INT', 4201 or die "Cannot signal 4201 with SIGINT: $!";
```

You can even use the => operator to automatically quote the signal name:

```
kill INT => 4201 or die "Cannot signal 4201 with SIGINT: $!";
```

On a Unix system, the *kill* command (not the Perl built-in) can translate between the signal number and the name:

```
$ kill -l 2
INT
```

Or, given a name, it can give you the number:

```
$ kill -l INT
2
```

With no argument to -l, it prints all the numbers and names:

```
$ kill -l
1) SIGHUP      2) SIGINT      3) SIGQUIT     4) SIGILL
5) SIGTRAP     6) SIGABRT     7) SIGEMT      8) SIGFPE
9) SIGKILL    10) SIGBUS     11) SIGSEGV    12) SIGSYS
13) SIGPIPE   14) SIGALRM    15) SIGTERM    16) SIGURG
17) SIGSTOP   18) SIGTSTP    19) SIGCONT    20) SIGCHLD
21) SIGTTIN   22) SIGTTOU    23) SIGIO      24) SIGXCPU
25) SIGXFSZ   26) SIGVTALRM  27) SIGPROF    28) SIGWINCH
29) SIGINFO   30) SIGUSR1    31) SIGUSR2
```

If you try to interrupt a process that no longer exists or isn't yours, you'll get a false return value.

You can also use this technique to see whether a process is still alive. A special signal number of 0 says, "Just check to see whether I *could* send a signal if I wanted to, but I don't want to, so don't actually send anything." So a process probe might look like:

```
unless (kill 0, $pid) {  
    warn "$pid has gone away!";  
}
```

Perhaps a little more interesting than sending signals is catching signals. Why might you want to do this? Well, suppose you have a program that creates files in */tmp*, and you normally delete those files at the end of the program. If someone presses Ctrl-C during the execution, that leaves trash in */tmp*, a very impolite thing to do. To fix this, you can create a signal handler that takes care of the cleanup:

```
my $temp_directory = "/tmp/myprog.$$"; # create files below here  
mkdir $temp_directory, 0700 or die "Cannot create  
$temp_directory: $!";  
  
sub clean_up {  
    unlink glob "$temp_directory/*";  
    rmdir $temp_directory;  
}  
  
sub my_int_handler {  
    &clean_up();  
    die "interrupted, exiting...\n";  
}  
  
$SIG{'INT'} = 'my_int_handler';  
...;  
# some unspecified code here  
# Time passes, the program runs, creates some temporary  
# files in the temp directory, maybe someone presses Ctrl-C  
...;  
# Now it's the end of normal execution  
&clean_up();
```

NOTE

The `File::Temp` module, which comes with Perl, can automatically clean up temporary files and directories.

The assignment into the special `%SIG` hash activates the handler (until revoked). The key is the name of the signal (without the constant `SIG` prefix), and the value is a string naming the subroutine, without the ampersand. From then on, if a `SIGINT` comes along, Perl stops whatever it's doing and jumps immediately to the subroutine. Your subroutine cleans up the temp files and then exits. (And if nobody presses Ctrl-C, we'll still call `&clean_up()` at the end of normal execution.)

If the subroutine returns rather than exiting, execution resumes right where the signal interrupted it. This can be useful if the signal needs to actually interrupt something rather than causing it to stop. For example, suppose processing each line of a file takes a few seconds, which is pretty slow, and you want to abort the overall processing when an interrupt is processed—but not in the middle of processing a line. Just set a flag in the signal procedure and check it at the end of each line's processing:

```
my $int_flag = 0;
$SIG{'INT'} = 'my_int_handler';
sub my_int_handler { $int_flag = 1; }

while( ... doing stuff .. ) {
    last if $int_flag;
    ...
}

exit();
```

For the most part, Perl will only handle a signal once it reaches a safe point to do so. For instance, Perl will not deliver most signals in the middle of allocating memory or rearranging its internal data structures. Perl delivers some signals, such as `SIGILL`, `SIGBUS`, and `SIGSEGV`, right away, so those are still unsafe. See the [perlipc documentation](#).

Exercises

See “[Answers to Chapter 15 Exercises](#)” for answers to these exercises:

1. [6] Write a program that changes to some particular (hardcoded) directory, like the system’s root directory, then executes the *ls -l* command to get a long-format directory listing in that directory. (If you use a non-Unix system, use your own system’s command to get a detailed directory listing.)
2. [10] Modify the previous program to send the output of the command to a file called *ls.out* in the current directory. The error output should go to a file called *ls.err*. (You don’t need to do anything special about the fact that either of these files may end up being empty.)
3. [8] Write a program to parse the output of the *date* command to determine the current day of the week. If the day of the week is a weekday, print *get to work*; otherwise, print *go play*. The output of the *date* command begins with *Mon* on a Monday. If you don’t have a *date* command on your non-Unix system, make a fake little program that simply prints a string like *date* might print. We’ll even give you this two-line program if you promise not to ask us how it works:

```
#!/usr/bin/perl
print localtime( ) . "\n";
```

4. [15] (Unix only) Write an infinite loop program that catches signals and reports which signal it caught and how many times it has seen that signal before. Exit if you catch the *INT* signal. If you can use the command-line *kill*, you can send signals like so:

```
$ kill -USR1 12345
```


If you can't use the command-line *kill*, write another program to send signals to it. You might be able to get away with a Perl one-liner:

```
$ perl -e 'kill HUP => 12345'
```

Chapter 16. Some Advanced Perl Techniques

What you've seen so far is the core of Perl, the part that you as a Perl user should understand. But there are many other techniques that, while not obligatory, are still valuable tools to have in your toolbox. We've gathered the most important of those for this chapter. This also segues into the continuation of this book, *Intermediate Perl*, which is your next step in Perl.

Don't be misled by the title of the chapter, though; the techniques here aren't especially more difficult to understand than those that you've already seen. They are "advanced" merely in the sense that they aren't necessary for beginners. The first time you read this book, you may want to skip (or skim) this chapter so you can get right to using Perl. Come back to it a month or two later, when you're ready to get even more out of Perl. Consider this entire chapter a huge footnote.

Slices

It often happens that you need to work with only a few elements from a given list. For example, the Bedrock Library keeps information about its patrons in a large file. Each line in the file describes one patron with six colon-separated fields: a person's name, library card number, home address, home phone number, work phone number, and number of items currently checked out. A little bit of the file looks something like this:

```
fred flintstone:2168:301 Cobblestone Way:555-1212:555-2121:3  
barney rubble:709918:299 Cobblestone Way:555-3333:555-3438:0
```

One of the library's applications needs only the card numbers and number of items checked out; it doesn't use any of the other data. You could use something like this to get only the fields you need:

```

while (<$fh>) {
    chomp;
    my @items = split /:/;
    my($card_num, $count) = ($items[1], $items[5]);
    ... # now work with those two variables
}

```

But you don't need the array `@items` for anything else; it seems like a waste. Maybe it would be better for you to assign the result of `split` to a list of scalars, like this:

```

my($name, $card_num, $addr, $home, $work, $count) = split /:/;

```

That avoids the unneeded array `@items`—but now you have four scalar variables that you don't really need. For this situation, some people make up a number of dummy variable names, like `$dummy_1`, that shows they really don't care about that element from the `split`. But Larry thought that was too much trouble, so he added a special use of `undef`. If you use `undef` as an item in a list you're assigning to, Perl simply ignores the corresponding element of the source list:

```

my(undef, $card_num, undef, undef, undef, $count) = split /:/;

```

Is this any better? Well, it has the advantage that you don't use any unneeded variables. But it has the disadvantage that you have to count `undefs` to tell which element is `$count`. And this becomes quite unwieldy if there are more elements in the list. For example, some people who wanted just the `mtime` value from `stat` would write code like this:

```

my(undef, undef, undef, undef, undef, undef, undef,
    undef, undef, $mtime) = stat $some_file;

```

If you use the wrong number of `undefs`, you get the `atime` or `ctime` by mistake, and that's a tough one to debug. There's a better way: Perl can index into a list as if it were an array. This is a *list slice*. Here, since the

`mtime` is item 9 in the list returned by `stat`, you can get it with a subscript:

```
my $mtime = (stat $some_file)[9];
```

NOTE

It's the 10th item, but the index number is 9, since the first item is at index 0. This is the same kind of zero-based indexing that we've used already with arrays. The [perlfunc documentation](#) helpfully numbers the list for you so you don't have to count them yourself.

Those parentheses are required around the list of items (in this case, the return value from `stat`). If you wrote it like this, it wouldn't work:

```
my $mtime = stat($some_file)[9]; # Syntax error!
```

A list slice has to have a subscript expression in square brackets after a list in parentheses. The parentheses holding the arguments to a function call don't count.

Going back to the Bedrock Library, the list you work with is the return value from `split`. You can now use a slice to pull out item 1 and item 5 with subscripts:

```
my $card_num = (split /\:\/)[1];  
my $count = (split /\:\/)[5];
```

Using a scalar-context slice like this (pulling just a single element from the list) isn't bad, but it would be more efficient and simpler if you didn't have to do the `split` twice. So let's not do it twice; let's get both values at once by using a list slice in list context:

```
my($card_num, $count) = (split /\:\/)[1, 5];
```

The indices pull out element 1 and element 5 from the list, returning those as a two-element list. When you assign that to the two `my` variables, you get

exactly what we wanted. You do the `slice` just once, and you set the two variables with a simple notation.

A slice is often the simplest way to pull a few items from a list. Here, you can pull just the first and last items from a list, using the fact that index `-1` means the last element:

```
my($first, $last) = (sort @names)[0, -1];
```

This way to get the minimum or maximum from a list is a bit wasteful, but this isn't a chapter about sorting. For a better way, see the functions in the `List::Util` module.

The subscripts of a slice may be in any order and may even repeat values. This example pulls five items from a list of 10:

```
my @names = qw{ zero one two three four five six seven eight nine
};
my @numbers = ( @names )[ 9, 0, 2, 1, 0 ];
print "Bedrock @numbers\n"; # says Bedrock nine zero two one
zero
```

Array Slice

That previous example could be made even simpler. When slicing elements from an array (as opposed to a list), the parentheses aren't needed. So we could have done the slice like this:

```
my @numbers = @names[ 9, 0, 2, 1, 0 ];
```

This isn't merely a matter of omitting the parentheses; this is actually a different notation for accessing array elements: an *array slice*. In [Chapter 3](#), we said that the at sign on `@names` meant “all of the elements.” Actually, in a linguistic sense, it's more like a plural marker, much like the letter “s” in words like “cats” and “dogs.” In Perl, the dollar sign means there's just one of something, but the at sign means there's a list of items.

A slice is always a list, so the array slice notation uses an at sign to indicate that. When you see something like `@names[...]` in a Perl program, you need to do just as Perl does and look at the at sign at the beginning as well as the square brackets at the end. The square brackets mean that you're indexing into an array, and the at sign means that you're getting a whole list of elements, not just a single one (which is what the dollar sign would mean). See [Figure 16-1](#).

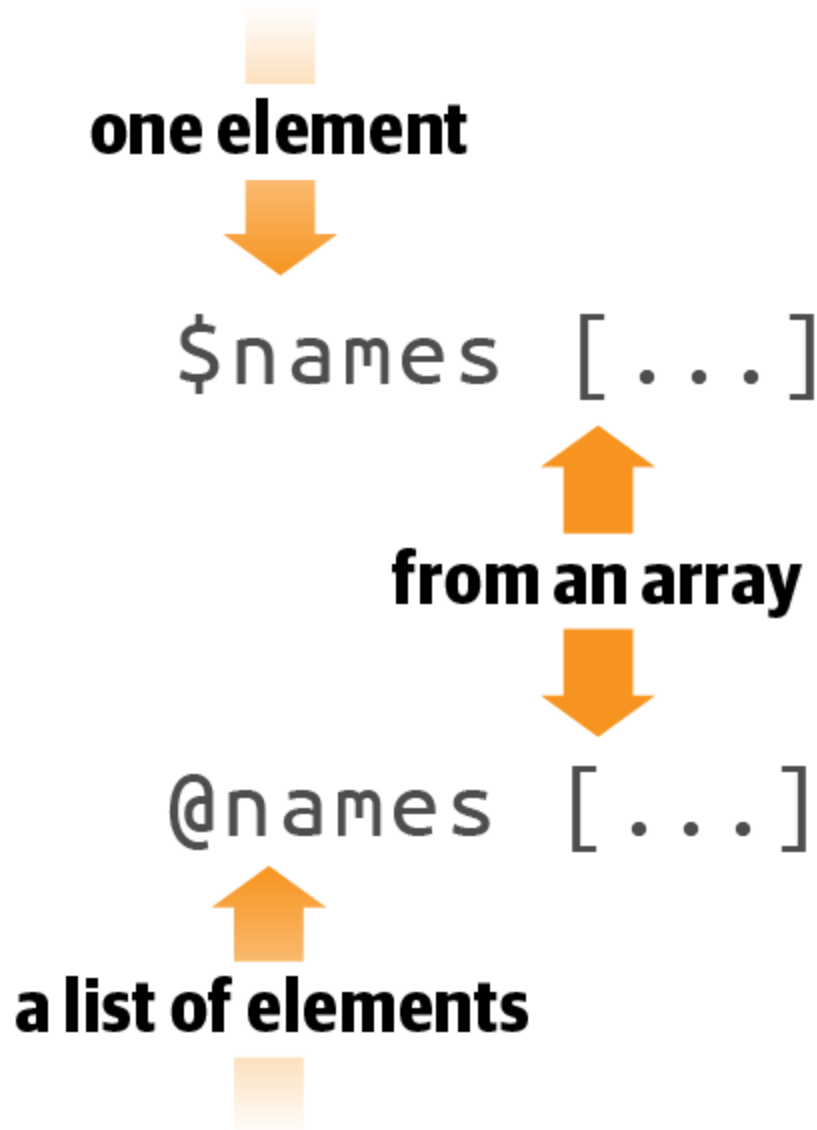


Figure 16-1. Array slices versus single elements

The punctuation mark at the front of the variable reference (either the dollar sign or the at sign) determines the context of the subscript expression. If

there's a dollar sign in front, the subscript expression is evaluated in a scalar context to get an index. But if there's an at sign in front, the subscript expression is evaluated in a list context to get a list of indices.

So you see that `@names[2, 5]` means the same list as `($names[2], $names[5])` does. If you want that list of values, you can simply use the array slice notation. Any place you might want to write the list, you can instead use the simpler array slice.

But you can use the slice in one place where you can't use a list. You can interpolate a slice directly into a string:

```
my @names = qw{ zero one two three four five six seven eight nine
};
print "Bedrock @names[ 9, 0, 2, 1, 0 ]\n";
```

If you were to interpolate `@names`, you'd get all of the items from the array, separated by spaces. If instead you interpolate `@names[9, 0, 2, 1, 0]`, that gives just those items from the array, separated by spaces. Let's go back to the Bedrock Library for a moment. Maybe now your program is updating Mr. Slate's address and phone number in the patron file because he just moved into a large new place in the Hollyrock Hills. If you have a list of information about him in `@items`, you could do something like this to update just those two elements of the array:

```
my $new_home_phone = "555-6099";
my $new_address = "99380 Red Rock West";
@items[2, 3] = ($new_address, $new_home_phone);
```

Once again, the array slice makes a more compact notation for a list of elements. In this case, that last line is the same as an assignment to `($items[2], $items[3])`, but more compact and efficient.

Hash Slice

In a way exactly analogous to an array slice, you can also slice some elements from a hash in a *hash slice*. Remember when three of your

characters went bowling, and you kept their bowling scores in the `%score` hash? You could pull those scores with a list of hash elements or with a slice. These two techniques are equivalent, although the second is more concise and efficient:

```
my @three_scores = ($score{"barney"}, $score{"fred"},  
$score{"dino"});  
  
my @three_scores = @score{ qw/ barney fred dino/ };
```

A slice is always a list, so the hash slice notation uses an at sign to indicate that. If it sounds as if we're repeating ourselves here, it's because we want to emphasize that hash slices are homologous to array slices. When you see something like `@score{ . . . }` in a Perl program, you need to do just as Perl does and look at the at sign at the beginning as well as the curly braces at the end. The curly braces mean that you're indexing into a hash; the at sign means that you're getting a whole list of elements, not just a single one (which is what the dollar sign would mean). See [Figure 16-2](#).

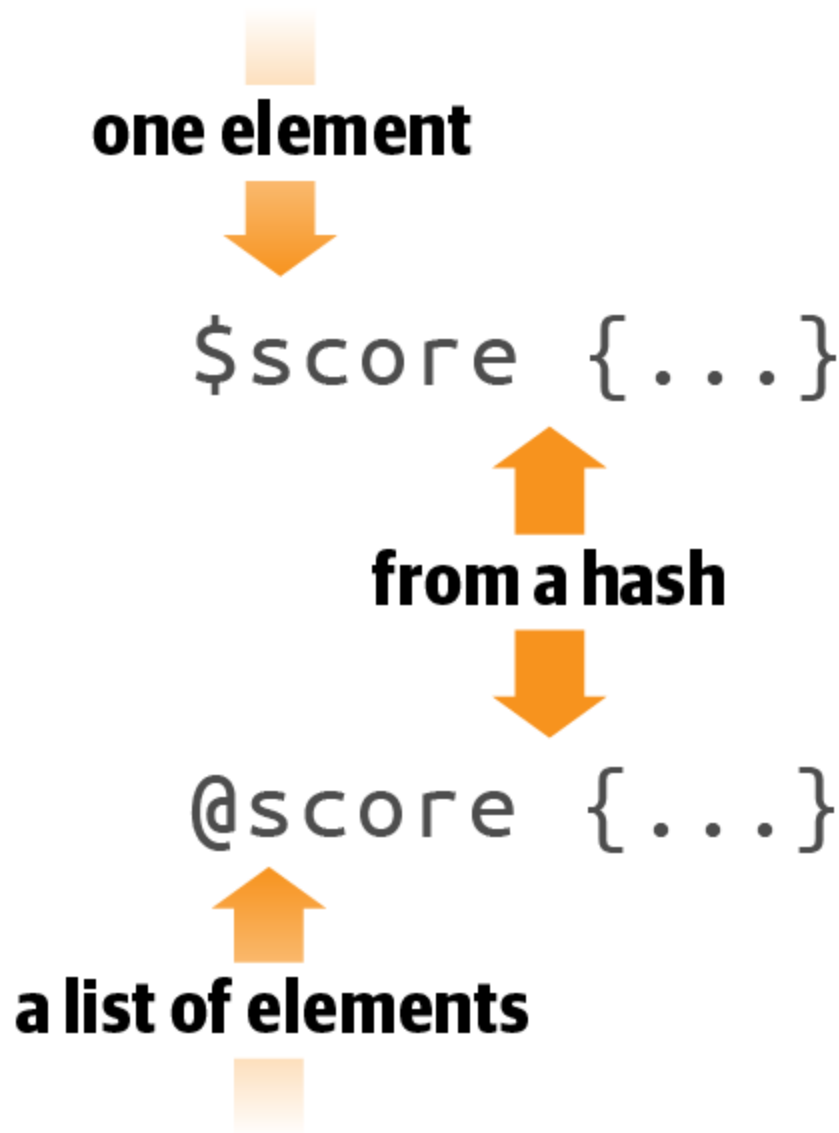


Figure 16-2. Hash slices versus single elements

As you saw with the array slice, the punctuation mark at the front of the variable reference (either the dollar sign or at sign) determines the context of the subscript expression. If there's a dollar sign in front, the subscript expression is evaluated in a scalar context to get a single key. But if there's an at sign in front, the subscript expression is evaluated in a list context to get a list of keys.

It's normal at this point to wonder why there's no percent sign (%) here, when we're talking about a hash. That's the marker that means there's a whole hash; a hash slice (like any other slice) is always a *list*, not a hash. In

Perl, the dollar sign means there's just one of something, but the at sign means there's a list of items, and the percent sign means there's an entire hash.

As you saw with array slices, a hash slice may be used instead of the corresponding list of elements from the hash, anywhere within Perl. So you can set your friends' bowling scores in the hash (without disturbing any other elements in the hash) in this simple way:

```
my @players = qw/ barney fred dino /;
my @bowling_scores = (195, 205, 30);
@score{ @players } = @bowling_scores;
```

That last line does the same thing as if you had assigned to the three-element list (`$score{"barney"}, $score{"fred"}, $score{"dino"}`).

A hash slice may be interpolated too. Here, you print out the scores for your favorite bowlers:

```
print "Tonight's players were: @players\n";
print "Their scores were: @score{@players}\n";
```

Key-Value Slices

Perl v5.20 introduced the *key-value slice* as a way to get out, well, the keys and values that go together. So far, in a hash slice, you got a list of values:

```
my @values = @score{@players};
```

You used an at sign in front of the hash's name because you get out a list of values. After that, `@values` is just the values. If you wanted to remember which keys they went with, you'd have to do extra work:

```
my %new_hash;
@new_hash{ @players } = @values;
```

Or you might try a map (coming up later in this chapter):

```
my %new_hash = map { $_ => $score{$_} } @players;
```

If that's what you want, v5.20 gives you a convenient syntax for it. This time, precede the hash name with a %:

```
use v5.20;  
  
my %new_hash = %score{@players};
```

Remember that sigils do not denote variable type; they communicate what you are doing with the variable. In this case, you want key-value pairs. That's a hashy sort of operation, so it gets % in front of it.

You can do this with arrays too. Think about the array indices as the keys:

```
my %first_last_scores = %bowling_scores[0,-1];
```

You still use a %, because it's still a hashy sort of operation even though it's an array variable. You can tell it's an array because you use the [] as the subscripting brackets.

Trapping Errors

Sometimes things don't always work out in your programs, but that doesn't mean you want your programs to merely complain before they stop themselves dead. Dealing with errors is a major part of the work of programming, and although we could fill a book on just that, we're still going to give you the introduction. See the third book in this series, *Mastering Perl*, for an in-depth examination of error handling in Perl.

Using eval

Sometimes your ordinary, everyday code can cause a fatal error in your program. Each of these typical statements could crash a program:

```

my $barney = $fred / $dino;          # divide-by-zero error?

my $wilma = '[abc]';
print "match\n" if /\A($wilma)/;    # illegal regular expression
error?

open my $caveman, '<', $fred          # user-generated error from die?
  or die "Can't open file '$fred' for input: $!";

```

You could go to some trouble to catch some of these, but it’s hard to get them all. How could you check the string `$wilma` to ensure it makes a valid regular expression? Fortunately, Perl provides a simple way to catch fatal errors—you can wrap the code in an `eval` block:

```

eval { $barney = $fred / $dino };

```

Now, even if `$dino` is zero, that line won’t crash your program. As soon as the `eval` encounters a normally fatal error, it stops the entire block and continues with the rest of the program. Notice that semicolon after the `eval` block. The `eval` is actually an expression (not a control structure, like `while` or `foreach`), so you need that semicolon at the end of the block.

The return value of the `eval` is the last evaluated expression, just like a subroutine. Instead of putting `$barney` on the inside of the `eval`, you could assign it the result of the `eval`, which allows you to declare `$barney` in the scope outside the `eval`:

```

my $barney = eval { $fred / $dino };

```

If that `eval` catches an error, it returns `undef`. You can use the `defined-or` operator to set a default value, such as `NaN` (“Not a Number”):

```

use v5.10;
my $barney = eval { $fred / $dino } // 'NaN';

```

When a normally fatal error happens during the execution of an `eval` block, the block is done running, but the program doesn’t crash.

When an `eval` finishes, you want to know whether it exited normally or whether it caught a fatal error. If the `eval` caught a fatal error, it returns `undef` and puts the error message in the `$@` special variable, perhaps something like: `Illegal division by zero at my_program line 12`. If there was no error, `$@` will be empty. Of course, that means `$@` is a useful Boolean (true/false) value, true if there was an error. You sometimes see code like this after an `eval` block:

```
use v5.10;
my $barney = eval { $fred / $dino } // 'NaN';
print "I couldn't divide by \"$dino: $@" if $@;
```

You can also check the return value, but only if you expect it to be defined if it works. In fact, you should prefer this form to the previous example if it works for your situation:

```
unless( defined eval { $fred / $dino } ) {
    print "I couldn't divide by \"$dino: $@" if $@;
}
```

Sometimes the part that you want to test has no meaningful return value even on success, so you can add one yourself. If the `eval` catches a failure, it won't get the final statement, which is just `1` in this case:

```
unless( eval { some_sub(); 1 } ) {
    print "I couldn't divide by \"$dino: $@" if $@;
}
```

In list context, a failed `eval` returns an empty list. In this line, `@averages` only gets two elements if the `eval` fails, because the `eval` doesn't contribute anything to the list:

```
my @averages = ( 2/3, eval { $fred / $dino }, 22/7 );
```

The `eval` block is just like every other Perl block, so it makes a new scope for lexical (`my`) variables and you can have as many statements as you like.

Here's an `eval` block hard at work guarding against many potential fatal errors:

```
foreach my $person (qw/ fred wilma betty barney dino pebbles /) {
    eval {
        open my $fh, '<', $person
            or die "Can't open file '$person': $!";

        my($total, $count);

        while (<$fh>) {
            $total += $_;
            $count++;
        }

        my $average = $total/$count;
        print "Average for file $person was $average\n";

        &do_something($person, $average);
    };

    if ($?) {
        print "An error occurred ($?), continuing\n";
    }
}
```

How many possible fatal errors can that `eval` trap? If there is an error in opening the file, you catch it. Calculating the average may divide by zero, but that won't prematurely stop your program. The `eval` even protects the call to the mysteriously named `&do_something` subroutine against fatal errors. This feature is handy if you have to call a subroutine written by someone else, and you don't know whether they've coded defensively enough to avoid crashing your program. Some people purposely use `die` to signal problems because they expect you to use `eval` to handle it. We'll talk about that more in a moment.

If an error occurs during the processing of one of the files you have in the `foreach` list, you get an error message but your program will go on to the next file without further complaint.

You can also nest `eval` blocks inside other `eval` blocks without Perl getting confused. The inner `eval` traps errors in its block, keeping them from reaching the outer blocks. Of course, after the inner `eval` finishes, if it caught an error you may wish to repost the error by using `die`, thereby letting the outer `eval` catch it. You could change the code to catch an error in the division separately:

```
foreach my $person (qw/ fred wilma betty barney dino pebbles /) {
    eval {
        open my $fh, '<', $person
        or die "Can't open file '$person': $!";

        my($total, $count);

        while (<$fh>) {
            $total += $_;
            $count++;
        }

        my $average = eval { $total/$count } // 'NaN'; # Inner eval
        print "Average for file $person was $average\n";

        &do_something($person, $average);
    };

    if ($?) {
        print "An error occurred ($?), continuing\n";
    }
}
```

There are four kinds of problems that `eval` can't trap. The first group are syntax errors in the literal source, such as mismatched quotes, missing semicolons, missing operands, or invalid literal regular expressions:

```
eval {
    print "There is a mismatched quote";
    my $sum = 42 +;
    /[abc/
    print "Final output\n";
};
```

The *perl* compiler catches those errors as it parses the source and stops its work before it starts to run the program. The `eval` can only catch errors once your Perl code is actually running.

The second group are the very serious errors that crash *perl* itself, such as running out of memory or getting an untrapped signal. This sort of error abnormally shuts down the *perl* interpreter itself, and since *perl* isn't running, there's no way it can trap these errors. Some of these errors are listed with an (X) code in the [perldiag documentation](#), if you're curious.

The third problem group that an `eval` block can't trap are warnings, either user-generated ones (from `warn`), or Perl's internally generated warnings from the `-w` command-line option or the `use warnings` pragma. There's a separate mechanism apart from `eval` for trapping warnings; see the explanation of the `__WARN__` pseudosignal in the [perlvar documentation](#) for the details.

The last sort of error isn't really an error, but this is a good place to note it. The `exit` operator terminates the program at once, even if you call it from a subroutine inside an `eval` block. When you call `exit`, you expect and intend for your program to stop. That's what's supposed to happen, and as such, `eval` doesn't prevent it from doing its work.

We should also mention that there's another form of `eval` that can be dangerous if it's mishandled. In fact, you sometimes run across someone who will say that you shouldn't use `eval` in your code for security reasons. They're (mostly) right that you should use `eval` only with great care, but they're talking about the *other* form of `eval`, sometimes called "eval of a string." That `eval` takes a string, compiles it as Perl code, then executes that code just as if you had typed it directly into your program. Notice that the result of any string interpolation has to be valid Perl code:

```
my $operator = 'unlink';
eval "$operator \@files";
```


If the keyword `eval` comes directly before a block of code in curly braces, as you saw for most of this section, there's no need to worry—that's the safe kind of `eval`.

More Advanced Error Handling

Different languages naturally handle errors in their own way, but a popular concept is the *exception*. You try some code and if anything goes wrong, the program *throws* an exception that it expects you to *catch*. With just basic Perl, you throw an exception with `die` and catch it with `eval`. You can inspect the value of `$@` to figure out what happened:

```
eval {  
    ...;  
    die "An unexpected exception message" if $unexpected;  
    die "Bad denominator" if $dino == 0;  
    $barney = $fred / $dino;  
}  
if ( $@ =~ /unexpected/ ) {  
    ...;  
}  
elsif( $@ =~ /denominator/ ) {  
    ...;  
}
```

There are many subtle problems with this sort of code, mostly based on the dynamic scope of the `$@` variable. In short, since `$@` is a special variable and your use of `eval` might be wrapped in a higher-level `eval` (even if you don't know about it), you need to ensure that an error you catch doesn't interfere with errors at the higher level:

NOTE

We use `local` here even though we never showed it to you. It replaces a variable's value everywhere in the program until the scope ends. At the end of the scope, the variable has its original value.

```

{
local $@; # don't stomp on higher-level errors

eval {
    ...;
    die "An unexpected exception message" if $unexpected;
    die "Bad denominator" if $dino == 0;
    $barney = $fred / $dino;
};
if ( $@ =~ /unexpected/ ) {
    ...;
}
elsif( $@ =~ /denominator/ ) {
    ...;
}
}

```

That's not the whole story, though, and it's a really tricky problem that's easy to get wrong. The `Try::Tiny` module solves most of this problem for you (and explains it too, if you really need to know). It's not included in the Standard Library, but you can get it from CPAN. The basic form looks like this:

```

use Try::Tiny;

try {
    ...; # some code that might throw errors
}
catch {
    ...; # some code to handle the error
}
finally {
    ...;
}

```

The `try` acts like the `eval` you just saw. The construct runs the `catch` block only if there was an error. It always runs the `finally` block, allowing you to do any cleanup you'd like to do. You don't need to have the `catch` or the `finally`, either. To simply ignore errors, you can just use the `try`:

```

my $barney = try { $fred / $dino };

```

You can use `catch` to handle the error. Instead of messing with `$@`, `Try::Tiny` puts the error message in `$_`. You can still access `$@`, but part of `Try::Tiny`'s purpose is to prevent the abuse of `$@`:

```
use v5.10;

my $barney =
  try { $fred / $dino }
  catch {
    say "Error was $_"; # not $@
  };
```

The `finally` block runs in either case: if there was an error or not. If it has arguments in `@_`, there was an error:

```
use v5.10;

my $barney =
  try { $fred / $dino }
  catch {
    say "Error was $_"; # not $@
  }
  finally {
    say @_ ? 'There was an error' : 'Everything worked';
  };
```

Picking Items from a List with `grep`

Sometimes you want only certain items from a list; maybe it's only the odd numbers from a list of numbers, or maybe it's only the lines mentioning `Fred` from a file of text. As you see in this section, picking some items from a list can be done simply with the `grep` operator.

Try this first one and get the odd numbers from a large list of numbers. You don't need anything new to do that:

```
my @odd_numbers;

foreach (1..1000) {
```

```
    push @odd_numbers, $_ if $_ % 2;  
}
```

That code uses the modulus operator (%), which you saw in [Chapter 2](#). If the number is even, that number “mod two” gives zero, which is false. But an odd number will give one; since that’s true, you only push the odd numbers onto `@odd_numbers`.

Now, there’s nothing wrong with that code as it stands—except that it’s a little longer to write and slower to run than it might be, since Perl provides the `grep` operator to act as a filter:

```
my @odd_numbers = grep { $_ % 2 } 1..1000;
```

That line gets a list of 500 odd numbers in one quick line of code. How does it work? The first argument to `grep` is a block that uses `$_` as a placeholder for each item in the list, and returns a Boolean (true/false) value. The remaining arguments are the list of items to search through. The `grep` operator will evaluate the expression once for each item in the list, much as your original `foreach` loop did. For the ones where the last expression of the block returns a true value, that element is included in the list that results from `grep`.

While the `grep` is running, Perl aliases `$_` to one element of the list after another. You saw this behavior before, in the `foreach` loop. It’s generally a bad idea to modify `$_` inside the `grep` expression because this will change the original data too.

The `grep` operator shares its name with a classic Unix utility that picks matching lines from a file by using regular expressions. You can do that with Perl’s `grep`, which is much more powerful. Here you select only the lines mentioning `fred` from a file:

```
my @matching_lines = grep { /\bfred\b/i } <$fh>;
```

There's a simpler syntax for `grep` too. If all you need for the selector is a simple expression (rather than a whole block), you can just use that expression, followed by a comma, in place of the block. Here's the simpler way to write that latest example:

```
my @matching_lines = grep /\bfred\b/i, <$fh>;
```

The `grep` operator also has a special scalar context mode in which it can tell you how many items it selected. What if you only wanted to count the matching lines from a file and you didn't care about the lines yourself? You could do that after you created the `@matching_lines` array:

```
my @matching_lines = grep /\bfred\b/i, <$fh>;
my $line_count = @matching_lines;
```

You can skip the intermediate array though (so you don't have to create that array and take up memory) by assigning to the scalar directly:

```
my $line_count = grep /\bfred\b/i, <$fh>;
```

Transforming Items from a List with `map`

Instead of a filter, you might want to change every item in a list. For example, suppose you have a list of numbers that should be formatted as “money numbers” for output, as with the subroutine `big_money` from [Chapter 14](#). You don't want to modify the original data; you need a modified copy of the list just for output. Here's one way to do that:

```
my @data = (4.75, 1.5, 2, 1234, 6.9456, 12345678.9, 29.95);
my @formatted_data;

foreach (@data) {
    push @formatted_data, big_money($_);
}
```

That looks similar in form to the example code used at the beginning of the previous section on `grep`, doesn't it? So it may not surprise you that the replacement code resembles the first `grep` example:

```
my @data = (4.75, 1.5, 2, 1234, 6.9456, 12345678.9, 29.95);

my @formatted_data = map { big_money($_) } @data;
```

The `map` operator looks much like `grep` because it has the same kind of arguments: a block that uses `$_`, and a list of items to process. And it operates in a similar way, evaluating the block once for each item in the list, with `$_` aliased to a different original list element each time. But `map` uses the last expression of the block differently; instead of giving a Boolean value, the final value actually becomes part of the resulting list. One other important difference is that the expression used by `map` is evaluated in a list context and may return any number of items, not necessarily one each time.

You can rewrite any `grep` or `map` statement as a `foreach` loop pushing items onto a temporary array. But the shorter way is typically more efficient and more convenient. Since the result of `map` or `grep` is a list, it can be passed directly to another function. Here we can print that list of formatted “money numbers” as an indented list under a heading:

```
print "The money numbers are:\n",
      map { sprintf("%25s\n", $_) } @formatted_data;
```

Of course, you could have done that processing all at once, without even the temporary array `@formatted_data`:

```
my @data = (4.75, 1.5, 2, 1234, 6.9456, 12345678.9, 29.95);
print "The money numbers are:\n",
      map { sprintf("%25s\n", big_money($_) ) } @data;
```

As you saw with `grep`, there's also a simpler syntax for `map`. If all you need for the selector is a simple expression (rather than a whole block), you can just use that expression, followed by a comma, in place of the block:

```
print "Some powers of two are:\n",
  map "\t" . ( 2 ** $_ ) . "\n", 0..15;
```

Fancier List Utilities

There are a couple of modules that you can use if you need fancier list handling in Perl. After all, many programs really are just a series of instructions moving lists around in various ways.

The `List::Util` module comes with the Standard Library and provides high-performance versions of common list processing utilities. These are implemented at the C level.

Suppose you wanted to know if a list contains an item that matches some condition. You don't need to get all of the elements, and you want to stop once you find the first matching element. You can't use `grep`, because it always scans the entire list, and if your list is very long, the `grep` might do a lot of extra, unnecessary work:

```
my $first_match;
foreach (@characters) {
    if (/\\bPebbles\\b/i) {
        $first_match = $_;
        last;
    }
}
```

That's a lot of code. Instead, you can use the `first` subroutine from `List::Util`:

```
use List::Util qw(first);
my $first_match = first { /\\bPebbles\\b/i } @characters;
```

In the Exercises for [Chapter 4](#), you created the `&total` subroutine. If you knew about `List::Util`, you wouldn't have done so much work:

```
use List::Util qw(sum);
my $total = sum( 1..1000 ); # 500500
```

Also in [Chapter 4](#), the `&max` subroutine did a lot of work to select the largest item from a list. You don't actually need to create that yourself since `List::Util`'s version can do it for you:

```
use List::Util qw(max);
my $max = max( 3, 5, 10, 4, 6 );
```

That `max` deals with numbers only. If you want to do it with strings (using string comparisons), you use `maxstr` instead:

```
use List::Util qw(maxstr);
my $max = maxstr( @strings );
```

If you want to randomize the order of elements in a list, you can use `shuffle`:

```
use List::Util qw(shuffle);
my @shuffled = shuffle(1..1000); # randomized order of elements
```

There's another module, `List::MoreUtils`, that has even more fancy subroutines. This one does not come with Perl, so you need to install it from CPAN. You can check if no, any, or all elements of a list match a condition. Each of these subroutines has the same block syntax of `grep`:

```
use List::MoreUtils qw(none any all);

if (none { $_ < 0 } @numbers) {
    print "No elements less than 0\n"
} elsif (any { $_ > 50 } @numbers) {
    print "Some elements over 50\n";
} elsif (all { $_ < 10 } @numbers) {
    print "All elements are less than 10\n";
}
```

If you want to deal with the list in groups of items, you can use the `natatime` (*N* at a time) to handle that for you:

```
use List::MoreUtils qw(natatime);
```



```

my $iterator = natatime 3, @array;
while( my @triad = $iterator->() ) {
    print "Got @triad\n";
}

```

If you need to combine two or more lists, you can use `mesh` to create the large list that interweaves all of the elements, even if the small arrays are not the same length:

```

use List::MoreUtils qw(mesh);

my @abc = 'a' .. 'z';
my @numbers = 1 .. 20;
my @dinosaurs = qw( dino );

my @large_array = mesh @abc, @numbers, @dinosaurs;

```

This takes the first element of `@abc` and makes it the first element of `@large_array`, then takes the first element of `@numbers` to make it the next element of `@large_array`, and then does the same with `@dinosaurs`. It then goes back to `@abc` to get its next element, and so on through all of the elements. The start of the resulting list in `@large_array` is:

```

a 1 dino b 2 c 3 ...

```

In that output, you should notice that there's an empty element between 2 and c (so there are two consecutive spaces after 2). When `mesh` runs out of elements from one of its input arrays, it fills in spots with `undef`. If you had warnings enabled, you'd get several of them.

There are many more useful and interesting subroutines in `List::MoreUtils`. Before you try to re-create what it already does, check its documentation.

Exercises

See “[Answers to Chapter 16 Exercises](#)” for answers to these exercises:

1. [30] Make a program that reads a list of strings from a file, one string per line, and then lets the user interactively enter patterns that may match some of the strings. For each pattern, the program should tell how many strings from the file matched, then which ones those were. Don’t reread the file for each new pattern; keep the strings in memory. The filename may be hardcoded in the file. If a pattern is invalid (for example, if it has unmatched parentheses), the program should simply report that error and let the user continue trying patterns. When the user enters a blank line instead of a pattern, the program should quit. (If you need a file full of interesting strings to try matching, try the file *sample_text* in the files you’ve surely downloaded by now from the O’Reilly website; see the [Preface](#).)
2. [15] Write a program to make a report of the access and modification times (in the epoch time) of the files in the current directory. Use `stat` to get the times, using a list slice to extract the elements. Report your results in three columns, like this:

<code>fred.txt</code>	1294145029	1290880566
<code>barney.txt</code>	1294197219	1290810036
<code>betty.txt</code>	1287707076	1274433310

3. [15] Modify your answer to Exercise 2 to report the times using the YYYY-MM-DD format. Use a map with `localtime` and a slice to turn the epoch times into the date strings that you need. Note the `localtime` documentation about the year and month values it returns. Your report should look like this:

<code>fred.txt</code>	2011-10-15	2011-09-28
<code>barney.txt</code>	2011-10-13	2011-08-11
<code>betty.txt</code>	2011-10-15	2010-07-24

Appendix A. Exercise Answers

This appendix contains the answers to the exercises that appear throughout the book.

Answers to Chapter 1 Exercises

1. This exercise is easy since we already gave you the program. Your job was to make it work:

```
print "Hello, world!\n";
```

If you have v5.10 or later, you can try `say`:

```
use v5.10;  
say "Hello, world!";
```

If you want to try it from the command line without creating a file, you can specify your program on the command line with the `-e` switch:

```
$ perl -e 'print "Hello, World\n"'
```

There's another switch, `-l`, that automatically adds the newline for you:

```
$ perl -le 'print "Hello, World"'
```

The quoting in Windows in *command.exe* (or *cmd.exe*) needs the double quotes on the outside, so you switch them:

```
C:\> perl -le "print 'Hello, World'"
```

You can save yourself some headaches with quoting by using the generalized quotes inside the shell quoting:

```
C:\> perl -le "print q(Hello, World)"
```

With v5.10 and later, you can use the `-E` switch to enable new features. That allows you to use `say`:

```
$ perl -E 'say q(Hello, World)'
```

We didn't expect you to try this on the command line, because we didn't tell you about that yet. Still, it's another way to do it. See [perlrun](#) for a complete listing of command-line switches and features.

2. The *perldoc* command should come with your *perl*, so you should be able to run it directly. If you can't find *perldoc*, you may have to install another package on your system. Ubuntu, for instance, puts it in the `perl-doc` package.
3. This program is easy too, as long as you got the previous exercise to work:

```
@lines = `perldoc -u -f atan2`;
foreach (@lines) {
    s/\w<(.*?)>/\U$1/g;
    print;
}
```

Answers to Chapter 2 Exercises

1. Here's one way to do it:

```
#!/usr/bin/perl
use warnings;
$pi = 3.141592654;
$circ = 2 * $pi * 12.5;
print "The circumference of a circle of radius 12.5 is
$circ.\n";
```

As you see, we started this program with a typical `#!` line; your path to Perl may vary. We also turned on warnings.

The first real line of code sets the value of `$pi` to our value of π . There are several reasons a good programmer will prefer to use a constant value like this: it takes time to type `3.141592654` into your program if you ever need it more than once. It may be a mathematical bug if you accidentally used `3.141592654` in one place and `3.14159` in another. There's only one line to check on to make sure you didn't accidentally type `3.141952654` and send your space probe to the wrong planet.

Modern Perls allow you to use fancier characters as variable names. We could have used the π character as the name if we told Perl that the source code included Unicode characters (see [Appendix C](#)):

```
#!/usr/bin/perl
use utf8;
use warnings;
$π = 3.141592654;
$circ = 2 * $π * 12.5;
print "The circumference of a circle of radius 12.5 is
$circ.\n";
```

Next we calculate the circumference, storing it in `$circ`, and we print it out in a nice message. The message ends with a newline character, because every line of a good program's output should end with a newline. Without it, you might end up with output looking something like this, depending on your shell's prompt:

```
The circumference of a circle of radius 12.5
is 78.53981635.bash-2.01$
```

Since the circumference isn't really `78.53981635.bash-2.01$`, this should probably be construed as a bug. So, use `\n` at the end of each line of output.

2. Here's one way to do it:

```
#!/usr/bin/perl
use warnings;
$pi = 3.141592654;
print "What is the radius? ";
chomp($radius = <STDIN>);
$circ = 2 * $pi * $radius;
print "The circumference of a circle of radius $radius is
$circ.\n";
```

This is just like the last one, except now we ask the user for the radius, and then we use `$radius` in every place where we previously used the hardcoded value `12.5`. If we had written the first program with more foresight, in fact, we would have a variable named `$radius` in that one as well. Note that if we hadn't used `chomp`, the mathematical formula would still have worked because a string like `"12.5\n"` is converted to the number `12.5` without any problem. But when we print out the message, it would look like this:

```
The circumference of a circle of radius 12.5 is
78.53981635.
```

Notice that the newline character is still in `$radius`, even though we've used that variable as a number. Since we had a space between `$radius` and the word `is` in the `print` statement, there's a space at the beginning of the second line of output. The moral of the story is: `chomp` your input unless you have a reason not to.

3. Here's one way to do it:

```
#!/usr/bin/perl
use warnings;
$pi = 3.141592654;
print "What is the radius? ";
chomp($radius = <STDIN>);
$circ = 2 * $pi * $radius;
if ($radius < 0) {
    $circ = 0;
}
print "The circumference of a circle of radius $radius is
$circ.\n";
```

Here we added the check for a bogus radius. Even if the given radius was impossible, the returned circumference would at least be nonnegative. You could have changed the given radius to be zero, and then calculated the circumference too; there's more than one way to do it. In fact, that's the Perl motto: *There Is More Than One Way To Do It*. And that's why each exercise answer starts with "Here's one way to do it..."

4. Here's one way to do it:


```

print "Enter first number: ";
chomp($one = <STDIN>);
print "Enter second number: ";
chomp($two = <STDIN>);
$result = $one * $two;
print "The result is $result.\n";

```

Notice that we've left off the `#!` line for this answer. In fact, from here on, we'll assume that you know it's there, so you don't need to read it each time.

Perhaps those are poor choices for variable names. In a large program, a maintenance programmer might think that `$two` should have the value of 2. In this short program, it probably doesn't matter, but in a large one we could have called them something more descriptive, with names like `$first_response`.

In this program, it wouldn't make any difference if we forgot to `chomp` the two variables `$one` and `$two`, since we never use them as strings once they've been set. But if next week our maintenance programmer edits the program to print a message like: The result of multiplying `$one` by `$two` is `$result.\n`, those pesky newlines will come back to haunt us. Once again, `chomp` unless you have a reason not to `chomp`—like in the next exercise.

5. Here's one way to do it:

```

print "Enter a string: ";
$str = <STDIN>;
print "Enter a number of times: ";
chomp($num = <STDIN>);
$result = $str x $num;
print "The result is:\n$result";

```

This program is almost the same as the last one, in a sense. We’re “multiplying” a string by a number of times, so we’ve kept the structure of the previous exercise. In this case, though, we didn’t want to `chomp` the first input item—the string—because the exercise asked for the strings to appear on separate lines. So, if the user entered `fred` and a newline for the string, and `3` for the number, we’d get a newline after each `fred`, just as we wanted.

In the `print` statement at the end, we put the newline before `$result` because we wanted to have the first `fred` printed on a line of its own. That is, we didn’t want output like this, with only two of the three `freds` aligned in a column:

```
The result is: fred
fred
fred
```

At the same time, we didn’t need to put another newline at the end of the `print` output because `$result` should already end with a newline.

In most cases, Perl won’t mind where you put spaces in your program; you can put in spaces or leave them out. But it’s important not to accidentally spell the wrong thing! If the `x` runs up against the preceding variable name `$str`, Perl will see `$strx`, which won’t work.

Answers to Chapter 3 Exercises

1. Here's one way to do it:

```
print "Enter some lines, then press Ctrl-D:\n";
@lines = <STDIN>;
@reverse_lines = reverse @lines;
print @reverse_lines;
```

...or, even more simply:

```
print "Enter some lines, then press Ctrl-D:\n";
print reverse <STDIN>;
```

Most Perl programmers would prefer the second one, as long as they don't need to keep the list of lines around for later use.

2. Here's one way to do it:

```
@names = qw/ fred betty barney dino wilma pebbles bamm-
bamm /;
print
"Enter some numbers from 1 to 7, one per line, then press
Ctrl-D:\n";
chomp(@numbers = <STDIN>);
foreach (@numbers) {
    print "$names[ $_ - 1 ]\n";
}
```

We have to subtract one from the index number so that the user can count from 1 to 7, even though the array is indexed from 0 to 6. Another way to accomplish this would be to have a dummy item in the @names array, like this:

```
@names = qw/ dummy_item fred betty barney dino wilma  
pebbles bamm-bamm /;
```

Give yourself extra credit if you checked to make sure that the user's choice of index was in fact in the range 1 to 7.

3. Here's one way to do it if you want the output all on one line:

```
chomp(@lines = <STDIN>);  
@sorted = sort @lines;  
print "@sorted\n";
```

...or, to get the output on separate lines:

```
print sort <STDIN>;
```

Answers to Chapter 4 Exercises

1. Here's one way to do it:

```
sub total {  
    my $sum; # private variable  
    foreach (@_) {  
        $sum += $_;  
    }  
    $sum;  
}
```

This subroutine uses `$sum` to keep a running total. At the start of the subroutine, `$sum` is `undef`, since it's a new variable. Then the `foreach` loop steps through the parameter list (from `@_`), using `$_` as the control variable. (Note: once again, there's no automatic connection between `@_`, the parameter array, and `$_`, the default variable for the `foreach` loop.)

The first time through the `foreach` loop, the first number (in `$_`) is added to `$sum`. Of course, `$sum` is `undef`, since nothing has been stored in there. But since we're using it as a number, which Perl sees because of the numeric operator `+=`, Perl acts as if it's already initialized to 0. Perl thus adds the first parameter to 0 and puts the total back in `$sum`.

The next time through the loop, the next parameter is added to `$sum`, which is no longer `undef`. The sum is placed back in `$sum`, and on through the rest of the parameters. Finally, the last line returns `$sum` to the caller.

There's a potential bug in this subroutine, depending on how you think of things. Suppose this subroutine was called with an empty parameter list (as we considered with the rewritten subroutine `&max` in the chapter text). In that case, `$sum` would be `undef`,

and that would be the return value. But in this subroutine, it would probably be “more correct” to return 0 as the sum of the empty list, rather than `undef`. (Of course, if you wish to distinguish the sum of an empty list from the sum of, say, (3, -5, 2), returning `undef` would be the right thing to do.)

If you don’t want a possibly undefined return value, though, it’s easy to remedy. Simply initialize `$sum` to zero rather than using the default of `undef`:

```
my $sum = 0;
```

Now the subroutine will always return a number, even if the parameter list was empty.

2. Here’s one way to do it:

```
# Remember to include &total from previous exercise!
print "The numbers from 1 to 1000 add up to ",
total(1..1000), ".\n";
```

Note that we can’t call the subroutine from inside the double-quoted string, so the subroutine call is another separate item being passed to `print`. The total should be 500500, a nice round number. And it shouldn’t take any noticeable time at all to run this program; passing a parameter list of 1,000 values is an everyday task for Perl.

3. Here’s one way to do it:

```
sub average {
    if (@_ == 0) { return }
    my $count = @_;
    my $sum = total(@_);           # from earlier
    exercise
```

```

    $sum/$count;
}

sub above_average {
    my $average = average(@_);
    my @list;
    foreach my $element (@_) {
        if ($element > $average) {
            push @list, $element;
        }
    }
    @list;
}

```

In `average`, we return without giving an explicit return value if the parameter list is empty. That gives the caller `undef` as the way to report that there's no average for an empty list. If the list wasn't empty, using `&total` makes it simple to calculate the average. We didn't even need to use temporary variables for `$sum` and `$count`, but doing so makes the code easier to read.

The second sub, `above_average`, simply builds up and returns a list of the desired items. (Why is the control variable named `$element`, instead of using Perl's favorite default, `$_`?) Note that this second sub uses a different technique for dealing with an empty parameter list.

4. To remember the last person that `greet` spoke to, use a state variable. It starts out as `undef`, which is how we figure out `Fred` is the first person it greets. At the end of the subroutine, we store the current `$name` in `$last_name` so we remember what it is next time:

```

use v5.10;

```

```

greet( 'Fred' );
greet( 'Barney' );

sub greet {
    state $last_person;

    my $name = shift;

    print "Hi $name! ";

    if( defined $last_person ) {
        print "$last_person is also here!\n";
    }
    else {
        print "You are the first one here!\n";
    }

    $last_person = $name;
}

```

5. This answer is similar to that for the preceding exercise, but this time we store all the names we have seen. Instead of using a scalar variable, we declare `@names` as a state variable and push each name onto it:

```

use v5.10;

greet( 'Fred' );
greet( 'Barney' );
greet( 'Wilma' );
greet( 'Betty' );

sub greet {
    state @names;

```



```
my $name = shift;

print "Hi $name! ";

if( @names ) {
    print "I've seen: @names\n";
}
else {
    print "You are the first one here!\n";
}

push @names, $name;
}
```

Answers to Chapter 5 Exercises

1. Here's one way to do it:

```
print reverse <>;
```

Well, that's pretty simple! But it works because `print` is looking for a list of strings to print, which it gets by calling `reverse` in a list context. And `reverse` is looking for a list of strings to reverse, which it gets by using the diamond operator in a list context. So, the diamond returns a list of all the lines from all the files of the user's choice. That list of lines is just what *cat* would print out. Now `reverse` reverses the list of lines, and `print` prints them out.

2. Here's one way to do it:

```
print "Enter some lines, then press Ctrl-D:\n"; # or
Ctrl-Z
chomp(my @lines = <STDIN>);

print "1234567890" x 7, "12345\n"; # ruler line to
column 75

foreach (@lines) {
    printf "%20s\n", $_;
}
```

Here we start by reading in and chomping all of the lines of text. Then we print the ruler line. Since that's a debugging aid, we'd generally comment out that line when the program is done. We could have typed "1234567890" again and again, or even used copy-and-paste to make a ruler line as long as we needed, but we chose to do it this way because it's kind of cool.

Now the `foreach` loop iterates over the list of lines, printing each one with the `%20s` conversion. If you chose to do so, you could have created a format to print the list all at once, without the loop:

```
my $format = "%20s\n" x @lines;
printf $format, @lines;
```

It's a common mistake to get 19-character columns. That happens when you say to yourself, "Hey, why do we `chomp` the input if we're only going to add the newlines back on later?" So you leave out the `chomp` and use a format of `"%20s"` (without a newline). And now, mysteriously, the output is off by one space. So, what went wrong?

The problem happens when Perl tries to count the spaces needed to make the right number of columns. If the user enters `hello` and a newline, Perl sees *six* characters, not five, since newline is a character. So it prints 14 spaces and a six-character string, sure that it gives the 20 characters you asked for in `"%20s"`. Oops.

Of course, Perl isn't looking at the contents of the string to determine the width; it merely checks the raw number of characters. A newline (or another special character, such as a tab or a null character) will throw things off.

3. Here's one way to do it:

```
print "What column width would you like? ";
chomp(my $width = <STDIN>);

print "Enter some lines, then press Ctrl-D:\n"; # or
Ctrl-Z
chomp(my @lines = <STDIN>);

print "1234567890" x (($width+9)/10), "\n";      # ruler
line as needed
```

```
foreach (@lines) {
    printf "%${width}s\n", $_;
}
```

Instead of interpolating the width into the format string, we could have used this:

```
foreach (@lines) {
    printf "%*s\n", $width, $_;
}
```

This is much like the previous one, but we ask for a column width first. We ask for that first because we can't ask for more input *after* the end-of-file indicator, at least on some systems. Of course, in the real world you'll generally have a better end-of-input indicator when getting input from the user, as we'll see in later exercise answers.

Another change from the previous exercise's answer is the ruler line. We used some math to cook up a ruler line that's at least as long as we need, as suggested as an extra-credit part of the exercise. Proving that our math is correct is an additional challenge. (Hint: consider possible widths of 50 and 51, and remember that the right side operand to \times is truncated, not rounded.)

To generate the format this time, we used the expression `"%${width}s\n"`, which interpolates `$width`. The curly braces are required to "insulate" the name from the following `s`; without the curly braces, we'd be interpolating `$widths`, the wrong variable. If you forgot how to use curly braces to do this, though, you could have written an expression like `'% ' . $width . "s\n"` to get the same format string.

The value of `$width` brings up another case where `chomp` is vital. If you don't `chomp` the width, the resulting format string would resemble `"%30\ns\n"`. That's not useful.

People who have seen `printf` before may have thought of another solution. Because `printf` comes to us from C, which doesn't have string interpolation, we can use the same trick that C programmers use. If an asterisk (*) appears in place of a numeric field width in a conversion, a value from the list of parameters will be used:

```
printf "%*s\n", $width, $_;
```

Answers to Chapter 6 Exercises

1. Here's one way to do it:

```
my %last_name = qw{
    fred flintstone
    barney rubble
    wilma flintstone
};
print "Please enter a first name: ";
chomp(my $name = <STDIN>);
print "That's $name $last_name{$name}.\n";
```

In this one, we used a `qw//` list (with curly braces as the delimiter) to initialize the hash. That's fine for this simple data set, and it's easy to maintain because each data item is a simple given name and simple family name, with nothing tricky. But if your data might contain spaces—for example, if `robert de niro` or `mary kay place` were to visit Bedrock—this simple method wouldn't work so well.

You might have chosen to assign each key-value pair separately, something like this:

```
my %last_name;
$last_name{"fred"} = "flintstone";
$last_name{"barney"} = "rubble";
$last_name{"wilma"} = "flintstone";
```

Note that (if you chose to declare the hash with `my`, perhaps because `use strict` was in effect) you must declare the hash before assigning any elements. You can't use `my` on only part of a variable, like this:

```
my $last_name{"fred"} = "flintstone"; # Oops!
```

The `my` operator works only with *entire* variables, never with just one element of an array or hash. Speaking of lexical variables, you may have noticed that the lexical variable `$name` is being declared inside the `chomp` function call; it is fairly common to declare each my variable as you need it, like this.

This is another case where `chomp` is vital. If someone enters the five-character string `"fred\n"` and we fail to `chomp` it, we'll be looking for `"fred\n"` as an element of the hash—and it's not there. Of course, `chomp` alone won't make this bulletproof; if someone enters `"fred \n"` (with a trailing space), with what we've seen so far, we don't have a way to tell that they meant `fred`.

If you added a check for whether the given key `exists` in the hash so that you'll give the user an explanatory message when they misspell a name, give yourself extra points for that.

2. Here's one way to do it:

```
my(@words, %count, $word);      # (optionally) declare our
variables
chomp(@words = <STDIN>);

foreach $word (@words) {
    $count{$word} += 1;          # or $count{$word} =
    $count{$word} + 1;
}

foreach $word (keys %count) {    # or sort keys %count
    print "$word was seen $count{$word} times.\n";
}
```

In this one, we declared all of the variables at the top. People who come to Perl from a background in languages like Pascal (where

variables are always declared “at the top”) may find that way more familiar than declaring variables as they are needed. Of course, we’re declaring these because we’re pretending that `use strict` may be in effect; by default, Perl won’t require such declarations.

Next we use the line-input operator, `<STDIN>`, in a list context to read all of the input lines into `@words`, and then we `chomp` those all at once. So `@words` is our list of words from the input (if the words were all on separate lines, as they should have been, of course).

Now the first `foreach` loop goes through all the words. That loop contains the most important statement of the entire program, the statement that says to add one to `$count{$word}` and put the result back in `$count{$word}`. Although you could write it either the short way (with the `+=` operator) or the long way, the short way is just a little bit more efficient, since Perl has to look up `$word` in the hash just once. For each word in the first `foreach` loop, we add one to `$count{$word}`. So, if the first word is `fred`, we add one to `$count{"fred"}`. Of course, since this is the first time we’ve seen `$count{"fred"}`, it’s `undef`. But since we’re treating it as a number (with the numeric `+=` operator, or with `+` if you wrote it the long way), Perl converts `undef` to 0 for us automatically. The total is 1, which is then stored back in `$count{"fred"}`.

The next time through that `foreach` loop, let’s say the word is `barney`. So, we add one to `$count{"barney"}`, bumping it up from `undef` to 1 as well.

Now let’s say the next word is `fred` again. When we add one to `$count{"fred"}`, which is already 1, we get 2. This goes back in `$count{"fred"}`, meaning that we’ve now seen `fred` twice.

When we finish the first `foreach` loop, then, we've counted how many times each word has appeared. The hash has a key for each (unique) word from the input, and the corresponding value is the number of times that word appeared.

So now, the second `foreach` loop goes through the keys of the hash, which are the unique words from the input. In this loop, we'll see each *different* word once. For each one, it says something like "fred was seen 3 times."

If you want the extra credit on this problem, you could put `sort` before `keys` to print out the keys in order. If there will be more than a dozen items in an output list, it's generally a good idea for them to be sorted so that a human being who is trying to debug the program will fairly quickly be able to find the item they want.

3. Here's one way to do it:

```
my $longest = 0;
foreach my $key ( keys %ENV ) {
    my $key_length = length( $key );
    $longest = $key_length if $key_length > $longest;
}

foreach my $key ( sort keys %ENV ) {
    printf "%-${longest}s  %s\n", $key, $ENV{$key};
}
```

In the first `foreach` loop, we go through all of the keys and use `length` to get their lengths. If the length we just measured is greater than the one we stored in `$longest`, we put the longer value in `$longest`.

Once we've gone through all of the keys, we use `printf` to print the keys and values in two columns. We use the same trick we used

in Exercise 3 from **Chapter 5** by interpolating `$longest` into the template string.

Answers to Chapter 7 Exercises

1. Here's one way to do it:

```
while (<>) {  
    if (/fred/) {  
        print;  
    }  
}
```

This is pretty simple. The more important part of this exercise is trying it out on the sample strings. It doesn't match `Fred`, showing that regular expressions are case-sensitive. (We'll see how to change that later.) It does match `frederick` and `Alfred`, since both of those strings contain the four-letter string `fred`. (Matching whole words only, so that `frederick` and `Alfred` wouldn't match, is another feature we'll see later.)

2. Here's one way to do it: change the pattern used in the first exercise's answer to `/[fF]red/`. You could also have tried `/(f|F)red/` or `/fred|Fred/`, but the character class is more efficient.
3. Here's one way to do it: change the pattern used in the first exercise's answer to `/\./`. The backslash is needed because the dot is a metacharacter, or you could use a character class: `/[.]/`.
4. Here's one way to do it: change the pattern used in the first exercise's answer to `/[A-Z][a-z]+/`.
5. Here's one way to do it: change the pattern used in the first exercise's answer to `/(\S)\1/`. The `\S` character class matches the nonwhitespace character, and the parentheses allow you to use the back reference `\1` to match the same character immediately following it.

6. Here's one way to do it:

```
while (<>) {  
    if (/wilma/) {  
        if (/fred/) {  
            print;  
        }  
    }  
}
```

This tests `/fred/` only after we find `/wilma/` matches, but `fred` could appear before or after `wilma` in the line; each test is independent of the other.

If you wanted to avoid the extra nested `if` test, you might have written something like this:

```
while (<>) {  
    if (/wilma.*fred|fred.*wilma/) {  
        print;  
    }  
}
```

This works because you'll either have `wilma` before `fred` or `fred` before `wilma`. If we had written just `/wilma.*fred/`, that wouldn't have matched a line like `fred and wilma flintstone`, even though that line mentions both of them.

Folks who know about the logical-and operator, which we showed in [Chapter 10](#), could do both tests `/fred/` and `/wilma/` in the same `if` conditional. That's more efficient, more scalable, and an all-around better way than the ones given here. But we haven't seen logical-and yet:

```
while (<>) {  
    if (/wilma/ && /fred/) {  
        print;  
    }  
}
```

The low-precedence short-circuit version works too:

```
while (<>) {  
    if (/wilma/ and /fred/) {  
        print;  
    }  
}
```

We made this an extra-credit exercise because many folks have a mental block here. We showed you an “or” operation (with the vertical bar, |), but we never showed you an “and” operation. That’s because there isn’t one in regular expressions. *Mastering Perl* revisits this example by using a regular expression lookahead, something even a bit too advanced for *Intermediate Perl*.

Answers to Chapter 8 Exercises

1. There's one easy way to do it, and we showed it back in the chapter body. But if your output isn't saying `before<match>after` as it should, you've chosen a hard way to do it.
2. Here's one way to do it:

```
/a\b/
```

(Of course, that's a pattern for use inside the pattern test program!) If your pattern mistakenly matches `barney`, you probably needed the word-boundary anchor.

3. Here's one way to do it:

```
#!/usr/bin/perl
while (<STDIN>) {
    chomp;
    if (/(\b\w*a\b)/) {
        print "Matched: |$`<$&>$'|\n";
        print "\$1 contains '$1'\n";          # The new output
line
    } else {
        print "No match: |$_|\n";
    }
}
```

This is the same test program (with a new pattern), except that the one marked line has been added to print out `$1`.

The pattern uses a pair of `\b` word-boundary anchors inside the parentheses, although the pattern works the same way when they are placed outside. That's because anchors correspond to a place in the string but not to any characters in the string: anchors have “zero width.”

Admittedly, the first `\b` anchor isn't really needed, due to details about greediness that we won't go into here. But it may help a tiny bit with efficiency, and it certainly helps with clarity—and in the end, that one wins out.

4. This exercise answer is the same as the previous exercise answer, but with a slightly different regular expression:

```
#!/usr/bin/perl

use v5.10;

while (<STDIN>) {
    chomp;
    if (/(?<word>\b\w*a\b)/) {
        print "Matched: |$`<$&>$'|\n";
        print "'word' contains '$+{word}'\n";      # The new
output line
    } else {
        print "No match: |$_|\n";
    }
}
```

5. Here's one way to do it:

```
m!
    (\b\w+a\b)      # $1: a word ending in a
    (.{0,5})        # $2: up to five characters following
!xs                # /x and /s modifiers
```

(Don't forget to add code to display `$2`, now that you have two memory variables. If you change the pattern to have just one again, you can simply comment out the extra line.) If your pattern doesn't match just plain `wilma` anymore, perhaps you require zero or

more characters instead of one or more. You may have omitted the `/s` modifier, since there shouldn't be newlines in the data. (Of course, if there are newlines in the data, the `/s` modifier could make for different output.)

6. Here's one way to do it:

```
while (<>) {  
    chomp;  
    if (/s\z/) {  
        print "$_#\n";  
    }  
}
```

We used the pound sign (#) as the marker character.

Answers to Chapter 9 Exercises

1. Here's one way to do it:

```
/( $what ) {3}/
```

Once `$what` has been interpolated, this gives a pattern resembling `/(fred|barney){3}/`. Without the parentheses, the pattern would be something like `/fred|barney{3}/`, which is the same as `/fred|barneyyy/`. So the parentheses are required.

2. Here's one way to do it:

```
my $in = $ARGV[0];
if (! defined $in) {
    die "Usage: $0 filename";
}

my $out = $in;
$out =~ s/(\.\w+)?$/.out/;

if (! open $in_fh, '<', $in ) {
    die "Can't open '$in': $!";
}

if (! open $out_fh, '>', $out ) {
    die "Can't write '$out': $!";
}

while (<$in_fh) {
    s/Fred/Larry/gi;
    print $out_fh $_;
}
```

This program begins by naming its one and only command-line parameter, and complaining if it didn't get it. Then it copies that to `$out` and does a substitution to change the file extension, if any, to `.out`. (It would be sufficient, though, to merely append `.out` to the filename.)

Once the filehandles `$in_fh` and `$out_fh` are opened, the real program can begin. If you didn't use both options `/g` and `/i`, take off half a point, since *every* `fred` and `Fred` should be changed.

3. Here's one way to do it:

```
while (<$in_fh) {
    chomp;
    s/Fred/\n/gi;          # Replace all FREDs
    s/Wilma/Fred/gi;       # Replace all WILMAs
    s/\n/Wilma/g;         # Replace the placeholder
    print $out_fh "$_\n";
}
```

This replaces the loop from the previous program, of course. To do this kind of a swap, we need to have some “placeholder” string that doesn't otherwise appear in the data. By using `chomp` (and adding the newline back for the output), we ensure that a newline (`\n`) can be the placeholder. (You could choose some other unlikely string as the placeholder. Another good choice would be the NUL character, `\0`.)

4. Here's one way to do it:

```
$^I = ".bak";             # make backups
while (<>) {
    if (/^A#!/) {          # is it the shebang line?
        $_ .= "## Copyright (C) 20XX by Yours Truly\n";
    }
}
```

```

    print;
}

```

Invoke this program with the filenames you want to update. For example, if you've been naming your exercises *ex01-1*, *ex01-2*, and so on, so that they all begin with *ex* . . . , you would use:

```

./fix_my_copyright ex*

```

5. To keep from adding the copyright twice, we have to make two passes over the files. First, we'll make a "set" with a hash where the keys are the filenames and the values don't matter (although we'll use 1 for convenience):

```

my %do_these;
foreach (@ARGV) {
    $do_these{$_} = 1;
}

```

Next, we'll examine the files and remove from our to-do list any file that already contains the copyright. The current filename is in `$ARGV`, so we can use that as the hash key:

```

while (<>) {
    if (/\\A## Copyright/) {
        delete $do_these{$ARGV};
    }
}

```

Finally, it's the same program as before, once we've reestablished a reduced list of names in `@ARGV`:

```

@ARGV = sort keys %do_these;
$I = ".bak";           # make backups

```

```
exit unless @ARGV; # no arguments reads from standard
input!
while (<>) {
    if (/^A#!/) {          # is it the shebang line?
        $_ .= "## Copyright (c) 20XX by Yours Truly\n";
    }
    print;
}
```

Answers to Chapter 10 Exercises

1. Here's one way to do it:

```
my $secret = int(1 + rand 100);  
# This next line may be uncommented during debugging  
# print "Don't tell anyone, but the secret number is  
$secret.\n";  
  
while (1) {  
    print "Please enter a guess from 1 to 100: ";  
    chomp(my $guess = <STDIN>);  
    if ($guess =~ /quit|exit|\A\s*\z/i) {  
        print "Sorry you gave up. The number was $secret.\n";  
        last;  
    } elsif ($guess < $secret) {  
        print "Too small. Try again!\n";  
    } elsif ($guess == $secret) {  
        print "That was it!\n";  
        last;  
    } else {  
        print "Too large. Try again!\n";  
    }  
}
```

The first line picks out our secret number from 1 to 100. Here's how it works. First, `rand` is Perl's random number function, so `rand 100` gives us a random number in the range from 0 up to (but not including) 100. That is, the largest possible value of that expression is something like 99.999. Adding one gives a number from 1 to 100.999, then the `int` function truncates that, giving a result from 1 to 100, as we needed.

The commented-out line can be helpful during development and debugging, or if you like to cheat. The main body of this program is the infinite `while` loop. That will keep asking for guesses until we execute `last`.

It's important that we test the possible strings before the numbers. If we didn't, do you see what would happen when the user types `quit`? That would be interpreted as a number (probably giving a warning message, if warnings were turned on), and since the value as a number would be zero, the poor user would get the message that their guess was too small. We might never get to the string tests, in that case.

Another way to make the infinite loop here would be to use a naked block with `redo`. It's not more or less efficient; merely another way to write it. Generally, if you expect to mostly loop, it's good to write `while`, since that loops by default. If looping will be the exception, a naked block may be a better choice.

2. This program is a slight modification to the previous answer. We want to print the secret number while we are developing the program, so we print the secret number if the variable `$Debug` has a true value. The value of `$Debug` is either the value that we already set as an environment variable, or 1 by default. By using the `//` operator, we won't set it to 1 unless the `$ENV{DEBUG}` is undefined:

```
use v5.10;
```

```
my $Debug = $ENV{DEBUG} // 1;
```

```
my $secret = int(1 + rand 100);
```

```
print "Don't tell anyone, but the secret number is
```

```
$secret.\n"
    if $Debug;
```

To do this without features introduced in v5.10, we just have to do a little more work:

```
my $Debug = defined $ENV{DEBUG} ? $ENV{DEBUG} : 1;
```

3. Here's one way to do it, which steals from the answer to Exercise 3 in [Chapter 6](#).

At the top of the program, we set some environment variables. The keys `ZERO` and `EMPTY` have false but defined values, and the key `UNDEFINED` has no value.

Later, in the `printf` argument list, we use the `//` operator to select the string `(undefined value)` only when `$ENV{$key}` is not a defined value:

```
use v5.10;

$ENV{ZERO}      = 0;
$ENV{EMPTY}     = '';
$ENV{UNDEFINED} = undef;

my $longest = 0;
foreach my $key ( keys %ENV ) {
    my $key_length = length( $key );
    $longest = $key_length if $key_length > $longest;
}

foreach my $key ( sort keys %ENV ) {
    printf "%-${longest}s  %s\n", $key, $ENV{$key} // "
(unknown value)";
}
```

By using `//` here, we don't disturb false values such as those in the keys `ZERO` and `EMPTY`.

To do this without Perl 5.10, we use the ternary operator instead:

```
printf "%-${longest}s  %s\n", $key,  
      defined $ENV{$key} ? $ENV{$key} : "(undefined  
value)";
```


Answers to Chapter 11 Exercises

1. This answer uses a hash reference (which you'll have to read about in *Intermediate Perl*), but we gave you the part to get around that. You don't have to know how it all works as long as you know it does work. You can get the job done and learn the details later.

Here's one way to do it:

```
use Module::CoreList;

my %modules = %{ $Module::CoreList::version{5.034} };

print join "\n", keys %modules;
```

And here's a bonus. With Perl's `postderef` feature, you could write this:

```
use v5.20;
use feature qw(postderef);
no warnings qw(experimental::postderef);

use Module::CoreList;

my %modules = $Module::CoreList::version{5.034}->%;

print join "\n", keys %modules;
```

See the blog post [“Use postfix dereferencing”](#) for more information. Or wait until we release the third edition of *Intermediate Perl*, which we will update with this new feature. We'll start working on it right after we finish this book.

2. Once you install `Time::Moment` from CPAN, you just have to create two dates and subtract them from each other. Remember to

get the date order correct:

```
use Time::Moment;
```

```
my $now = Time::Moment->now;
```

```
my $then = Time::Moment->new(  
    year      => $ARGV[0],  
    month     => $ARGV[1],  
    );
```

```
my $years = $then->delta_years( $now );
```

```
my $months = $then->delta_months( $now ) % 12;
```

```
printf "%d years and %d months\n", $years, $months;
```

Answers to Chapter 12 Exercises

1. Here's one way to do it:

```
foreach my $file (@ARGV) {
    my $attribs = &attributes($file);
    print "'$file' $attribs.\n";
}

sub attributes {
    # report the attributes of a given file
    my $file = shift @_;
    return "does not exist" unless -e $file;

    my @attrib;
    push @attrib, "readable" if -r $file;
    push @attrib, "writable" if -w $file;
    push @attrib, "executable" if -x $file;
    return "exists" unless @attrib;
    'is ' . join " and ", @attrib; # return value
}
```

In this solution, once again it's convenient to use a subroutine. The main loop prints one line of attributes for each file, perhaps telling us that 'cereal-killer' is executable or that 'sasquatch' does not exist.

The subroutine tells us the attributes of the given filename. Of course, if the file doesn't even exist, there's no need for the other tests, so we test for that first. If there's no file, we'll return early.

If the file does exist, we'll build a list of attributes. (Give yourself extra-credit points if you used the special `_` filehandle instead of `$file` on these tests, to keep from calling the system separately for each new attribute.) It would be easy to add additional tests like

the three we show here. But what happens if none of the attributes is true? Well, if we can't say anything else, at least we can say that the file exists, so we do. The `unless` clause uses the fact that `@attrib` will be true (in a Boolean context, which is a special case of a scalar context) if it's got any elements.

But if we've got some attributes, we'll join them with " and " and put "is " in front, to make a description like `is readable and writable`. This isn't perfect, however; if there are three attributes, it says the file `is readable and writable and executable`, which has too many ands, but we can get away with it. If you wanted to add more attributes to the ones this program checks for, you should probably fix it to say something like `is readable, writable, executable, and nonempty`. If that matters to you.

Note that if you somehow didn't put any filenames on the command line, this produces no output. This makes sense; if you ask for information on zero files, you should get zero lines of output. But let's compare that to what the next program does in a similar case, in the explanation that follows.

2. Here's one way to do it:

```
die "No file names supplied!\n" unless @ARGV;
my $oldest_name = shift @ARGV;
my $oldest_age = -M $oldest_name;

foreach (@ARGV) {
    my $age = -M;
    ($oldest_name, $oldest_age) = ($_, $age)
        if $age > $oldest_age;
}

printf "The oldest file was %s, and it was %.1f days
```

```
old.\n",  
    $oldest_name, $oldest_age;
```

This one starts right out by complaining if it didn't get any filenames on the command line. That's because it's supposed to tell us the oldest filename—and there ain't one if there aren't any files to check.

Once again, we're using the "high-water mark" algorithm. The first file is certainly the oldest one seen so far. We have to keep track of its age as well so that's in `$oldest_age`.

For each of the remaining files, we'll determine the age with the `-M` file test, just as we did for the first one (except that here we'll use the default argument of `$_` for the file test). The last-modified time is generally what people mean by the "age" of a file, although you could make a case for using a different one. If the age is more than `$oldest_age`, we'll use a list assignment to update both the name and age. We didn't have to use a list assignment, but it's a convenient way to update several variables at once.

We stored the age from `-M` in the temporary variable `$age`. What would have happened if we had simply used `-M` each time, rather than using a variable? Well, first, unless we used the special `_` filehandle, we would have been asking the operating system for the age of the file each time, a potentially slow operation (not that you'd notice unless you have hundreds or thousands of files, and maybe not even then). More importantly, though, we should consider what would happen if someone updated a file while we were checking it. That is, first we see the age of some file, and it's the oldest one seen so far. But before we can get back to use `-M` a second time, someone modifies the file and resets the timestamp to the current time. Now the age that we save into `$oldest_age` is actually the *youngest* age possible. The result would be that we'd

get the oldest file among the files tested from that point on, rather than the oldest overall; this would be a tough problem to debug!

Finally, at the end of the program, we use `printf` to print out the name and age, with the age rounded off to the nearest tenth of a day. Give yourself extra credit if you went to the trouble to convert the age to a number of days, hours, and minutes.

3. Here's one way to do it:

```
use v5.10;

say "Looking for my files that are readable and
writable";

die "No files specified!\n" unless @ARGV;

foreach my $file ( @ARGV ) {
    say "$file is readable and writable" if -o -r -w $file;
}
```

To use stacked file test operators, we need to use Perl 5.10 or later, so we start with the `use` statement to ensure that we have the right version of Perl. We `die` if there are no elements in `@ARGV`, and go through them with `foreach` otherwise.

We have to use three file test operators: `-o` to check if we own the file, `-r` to check that it is readable, and `-w` to check if it is writable. Stacking them as `-o -r -w` creates a composite test that only passes if all three of them are true, which is exactly what we want.

If we wanted to do this with a version before Perl 5.10, it's just a little more code. The `says` become `prints` with added newlines, and the stacked file tests become separate tests combined with the `&&` short-circuit operator:

```
print "Looking for my files that are readable and  
writable\n";
```

```
die "No files specified!\n" unless @ARGV;
```

```
foreach my $file ( @ARGV ) {  
    print "$file is readable and writable\n"  
        if( -w $file && -r _ && -o _ );  
}
```

Answers to Chapter 13 Exercises

1. Here's one way to do it, with a `glob`:

```
print "Which directory? (Default is your home directory)
";
chomp(my $dir = <STDIN>);
if ($dir =~ /\A\s*\z/) {           # A blank line
    chdir or die "Can't chdir to your home directory: $!";
} else {
    chdir $dir or die "Can't chdir to '$dir': $!";
}

my @files = <*>;
foreach (@files) {
    print "$_\n";
}
```

First, we show a simple prompt, read the desired directory, and `chomp` it. (Without a `chomp`, we'd be trying to head for a directory that ends in a newline—legal in Unix, and therefore cannot be presumed to simply be extraneous by the `chdir` function.)

Then, if the directory name is nonempty, we'll change to that directory, aborting on a failure. If empty, the home directory is selected instead.

Finally, a `glob` on “star” pulls up all the names in the (new) working directory, automatically sorted in alphabetical order, and they're printed one at a time.

2. Here's one way to do it:

```
print "Which directory? (Default is your home directory)
";
```



```

chomp(my $dir = <STDIN>);
if ($dir =~ /\A\s*\z/) {          # A blank line
    chdir or die "Can't chdir to your home directory: $!";
} else {
    chdir $dir or die "Can't chdir to '$dir': $!";
}

my @files = <.* *>;              ## now includes .*
foreach (sort @files) {          ## now sorts
    print "$_\n";
}

```

Two differences from previous one. First, the `glob` now includes “dot star,” which matches all the names that *do* begin with a dot. And second, we now must sort the resulting list because some of the names that begin with a dot must be interleaved appropriately, either before or after the list of things, without a beginning dot.

3. Here’s one way to do it:

```

print 'Which directory? (Default is your home directory)
';
chomp(my $dir = <STDIN>);
if ($dir =~ /\A\s*\z/) {          # A blank line
    chdir or die "Can't chdir to your home directory: $!";
} else {
    chdir $dir or die "Can't chdir to '$dir': $!";
}

opendir DOT, "." or die "Can't opendir dot: $!";
foreach (sort readdir DOT) {
    # next if /\A\./; ##    if we were skipping dot files
    print "$_\n";
}

```

Again, same structure as the previous two programs, but now we've chosen to open a directory handle. Once we've changed the working directory, we want to open the current directory, and we've shown that as the `DOT` directory handle.

Why `DOT`? Well, if the user asks for an absolute directory name, like `/etc`, there's no problem opening it. But if the name is relative, like `fred`, let's see what would happen. First, we `chdir` to `fred`, and then we want to use `opendir` to open it. But that would open `fred` in the new directory, not `fred` in the original directory. The only name we can be sure will mean "the current directory" is `.`, which always has that meaning (in Unix and similar systems, at least).

The `readdir` function pulls up all the names of the directory, which are then sorted and displayed. If we had done the first exercise this way, we would have skipped over the dot files—and that's handled by uncommenting the commented-out line in the `foreach` loop.

You may find yourself asking, "Why did we `chdir` first? You can use `readdir` and friends on any directory, not merely on the current directory." Primarily, we wanted to give the user the convenience of being able to get to their home directory with a single keystroke. But this could be the start of a general file-management utility program; maybe the next step would be to ask the user which of the files in this directory should be moved to offline tape storage, say.

4. Here's one way to do it:

```
unlink @ARGV;
```

...or, if you want to warn the user of any problems:

```
foreach (@ARGV) {
    unlink $_ or warn "Can't unlink '$_': $!,
continuing...\n";
}
```

Here, each item from the command-invocation line is placed individually into `$_`, which is then used as the argument to `unlink`. If something goes wrong, the warning gives a clue about why.

5. Here's one way to do it:

```
use File::Basename;
use File::Spec;

my($source, $dest) = @ARGV;

if (-d $dest) {
    my $basename = basename $source;
    $dest = File::Spec->catfile($dest, $basename);
}

rename $source, $dest
    or die "Can't rename '$source' to '$dest': $!\n";
```

The workhorse in this program is the last statement, but the remainder of the program is necessary when we are renaming into a directory. First, after declaring the modules we're using, we name the command-line arguments sensibly. If `$dest` is a directory, we need to extract the basename from the `$source` name and append it to the directory (`$dest`). Finally, once `$dest` is patched up if needed, the `rename` does the deed.

6. Here's one way to do it:

```

use File::Basename;
use File::Spec;

my($source, $dest) = @ARGV;

if (-d $dest) {
    my $basename = basename $source;
    $dest = File::Spec->catfile($dest, $basename);
}

link $source, $dest
    or die "Can't link '$source' to '$dest': $!\n";

```

As the hint in the exercise description said, this program is much like the previous one. The difference is that we'll `link` rather than `rename`. If your system doesn't support hard links, you might have written this as the last statement:

```

print "Would link '$source' to '$dest'.\n";

```

7. Here's one way to do it:

```

use File::Basename;
use File::Spec;

my $symlink = $ARGV[0] eq '-s';
shift @ARGV if $symlink;

my($source, $dest) = @ARGV;
if (-d $dest) {
    my $basename = basename $source;
    $dest = File::Spec->catfile($dest, $basename);
}

```

```

if ($symlink) {
    symlink $source, $dest
    or die "Can't make soft link from '$source' to
'$dest': $!\n";
} else {
    link $source, $dest
    or die "Can't make hard link from '$source' to
'$dest': $!\n";
}

```

The first few lines of code (after the two `use` declarations) look at the first command-line argument, and if it's `-s`, we're making a symbolic link, so we note that as a true value for `$symlink`. If we saw that `-s`, we then need to get rid of it (in the next line). The next few lines are cut-and-pasted from the previous exercise answers. Finally, based on the truth of `$symlink`, we'll choose to create either a symbolic link or a hard link. We also updated the dying words to make it clear which kind of link we were attempting.

8. Here's one way to do it:

```

foreach ( glob( '.* *' ) ) {
    my $dest = readlink $_;
    print "$_ -> $dest\n" if defined $dest;
}

```

Each item resulting from the `glob` ends up in `$_` one by one. If the item is a symbolic link, then `readlink` returns a defined value, and the location is displayed. If not, the condition fails and we skip over it.

Answers to Chapter 14 Exercises

1. Here's one way to do it:

```
my @numbers;
push @numbers, split while <>;
foreach (sort { $a <=> $b } @numbers) {
    printf "%20g\n", $_;
}
```

That second line of code is too confusing, isn't it? Well, we did that on purpose. Although we recommend that you write clear code, some people like writing code that's as hard to understand as possible, so we want you to be prepared for the worst. Someday you'll need to maintain confusing code like this.

Since that line uses the `while` modifier, it's the same as if it were written in a loop like this:

```
while (<>) {
    push @numbers, split;
}
```

That's better, but maybe it's still a little unclear. (Nevertheless, we don't have a quibble about writing it this way. This one is on the correct side of the "too hard to understand at a glance" line.) The `while` loop is reading the input one line at a time (from the user's choice of input sources, as shown by the diamond operator), and `split` is, by default, splitting that on whitespace to make a list of words—or in this case, a list of numbers. The input is just a stream of numbers separated by whitespace, after all. Either way you write it, then, that `while` loop will put all of the numbers from the input into `@numbers`.

The `foreach` loop takes the sorted list and prints each item on its own line, using the `%20g` numeric format to put them in a right-justified column. You could have used `%20s` instead. What difference would that make? Well, that's a string format, so it would have left the strings untouched in the output. Did you notice that our sample data included both `1.50` and `1.5`, and both `04` and `4`? If you printed those as strings, the extra zero characters will still be in the output; but `%20g` is a numeric format, so equal numbers will appear identically in the output. Either format could potentially be correct, depending on what you're trying to do.

2. Here's one way to do it:

```
# don't forget to incorporate the hash %last_name,
# either from the exercise text or the downloaded file

my @keys = sort {
    "\L$last_name{$a}" cmp "\L$last_name{$b}" # by last
name
    or
    "\L$a" cmp "\L$b" # by first
name
} keys %last_name;

foreach (@keys) {
    print "$last_name{$_}, $_\n"; #
Rubble,Bamm-Bamm
}
```

There's not much to say about this one; we put the keys in order as needed, then print them out. We chose to print them in last-name-comma-first-name order just for fun; the exercise description left that up to you.

3. Here's one way to do it:

```

print "Please enter a string: ";
chomp(my $string = <STDIN>);
print "Please enter a substring: ";
chomp(my $sub = <STDIN>);

my @places;

for (my $pos = -1; ; ) {                # tricky use of
three-part for loop
    $pos = index($string, $sub, $pos + 1); # find next
position
    last if $pos == -1;
    push @places, $pos;
}

print "Locations of '$sub' in '$string' were: @places\n";

```

This one starts out simply enough, asking the user for the strings and declaring an array to hold the list of substring positions. But once again, as we see in the `for` loop, the code seems to have been “optimized for cleverness,” which should be done only for fun, never in production code. But this actually shows a valid technique, which could be useful in some cases, so let’s see how it works.

The `my` variable `$pos` is declared private to the scope of the `for` loop, and it starts with a value of `-1`. So as not to keep you in suspense about this variable, we’ll tell you right now that it’s going to hold a position of the substring in the larger string. The test and increment sections of the `for` loop are empty, so this is an infinite loop. (Of course, we’ll eventually break out of it, in this case with `last`.)

The first statement of the loop body looks for the first occurrence of the substring at or after position `$pos + 1`. That means that on

the first iteration, when `$pos` is still `-1`, the search will start at position `0`, the start of the string. The location of the substring is stored back in `$pos`. Now, if that was `-1`, we're done with the `for` loop, so `last` breaks out of the loop in that case. If it wasn't `-1`, then we save the position into `@places` and go around the loop again. This time, `$pos + 1` means that we'll start looking for the substring just after the previous place where we found it. And so we get the answers we wanted and the world is once again a happy place.

If you didn't want that tricky use of the `for` loop, you could accomplish the same result as shown here:

```
{
  my $pos = -1;
  while (1) {
    ... # Same loop body as the for loop used earlier
  }
}
```

The naked block on the outside restricts the scope of `$pos`. You don't have to do that, but it's often a good idea to declare each variable in the smallest possible scope. This means we have fewer variables "alive" at any given point in the program, making it less likely that we'll accidentally reuse the name `$pos` for some new purpose. For the same reason, if you don't declare a variable in a small scope, you should generally give it a longer name that's thereby less likely to be reused by accident. Maybe something like `$substring_position` would be appropriate in this case.

On the other hand, if you were *trying* to obfuscate your code (shame on you!), you could create a monster like this (shame on us!):

```

for (my $pos = -1; -1 !=
    ($pos = index
        +$string,
        +$sub,
        +$pos
        +1
    );
push @places, (((+($pos)))) {
    'for ($pos != 1; # ;$pos++) {
        print "position $pos\n";#;' ;# ' } pop @places;
    }
}

```

That even trickier code works in place of the original tricky `for` loop. By now, you should know enough to be able to decipher that one on your own, or to obfuscate code in order to amaze your friends and confound your enemies. Be sure to use these powers only for good, never for evil.

Oh, and what did you get when you searched for `t` in `This is a test.`? It's at positions 10 and 13. It's not at position 0; since the capitalization doesn't match, the substring doesn't match.

Answers to Chapter 15 Exercises

1. Here's one way to do it:

```
chdir '/' or die "Can't chdir to root directory: $!";  
exec 'ls', '-l' or die "Can't exec ls: $!";
```

The first line changes the current working directory to the root directory, as our particular hardcoded directory. The second line uses the multiple-argument `exec` function to send the result to standard output. We could have used the single-argument form just as well, but it doesn't hurt to do it this way.

2. Here's one way to do it:

```
open STDOUT, '>', 'ls.out' or die "Can't write to ls.out:  
$!";  
open STDERR, '>', 'ls.err' or die "Can't write to ls.err:  
$!";  
chdir '/' or die "Can't chdir to root directory: $!";  
exec 'ls', '-l' or die "Can't exec ls: $!";
```

The first and second lines reopen `STDOUT` and `STDERR` to a file in the current directory (before we change directories). Then, after the directory change, the directory listing command executes, sending the data back to the files opened in the original directory.

Where would the message from the last `die` go? Well, it would go into *ls.err*, of course, since that's where `STDERR` is going at that point. The `die` from `chdir` would go there too. But where would the message go if we can't reopen `STDERR` on the second line? It goes to the old `STDERR`. When reopening the three standard filehandles (`STDIN`, `STDOUT`, and `STDERR`), the old filehandles are still open.

3. Here's one way to do it:

```
if (`date` =~ /\AS/) {  
    print "go play!\n";  
} else {  
    print "get to work!\n";  
}
```

Well, since both Saturday and Sunday start with an S, and the day of the week is the first part of the output of the *date* command, this is pretty simple. Just check the output of the *date* command to see if it starts with S. There are many harder ways to do this program, and we've seen most of them in our classes.

If we had to use this in a real-world program, though, we'd probably use the pattern `/\A(Sat|Sun)/`. It's a tiny bit less efficient, but that hardly matters; besides, it's so much easier for the maintenance programmer to understand.

4. To catch some signals, we set up signal handlers. Just with the techniques we show in this book, we have a bit of repetitive work to do. In each handler subroutine, we set up a `state` variable so we can count the number of times we call that subroutine. We use a `foreach` loop to then assign the right subroutine name to the appropriate key in `%SIG`. At the end, we create an infinite loop so the program runs indefinitely:

```
use v5.10;  
  
sub my_hup_handler { state $n; say 'Caught HUP: ', ++$n  
}  
sub my_usr1_handler { state $n; say 'Caught USR1: ', ++$n  
}  
sub my_usr2_handler { state $n; say 'Caught USR2: ', ++$n  
}
```

```

sub my_int_handler { say 'Caught INT. Exiting.'; exit }

say "I am $$";

foreach my $signal ( qw(int hup usr1 usr2) ) {
    $SIG{ uc $signal } = "my_${signal}_handler";
}

while(1) { sleep 1 };

```

We need another terminal session to run a program to send the signals:

```

$ kill -HUP 61203
$ perl -e 'kill HUP => 61203'
$ perl -e 'kill USR2 => 61203'

```

The output shows the running count of signals as we catch them:

```

$ perl signal_catcher
I am 61203
Caught HUP: 1
Caught HUP: 2
Caught USR2: 1
Caught HUP: 3
Caught USR2: 2
Caught INT. Exiting.

```

Answers to Chapter 16 Exercises

1. Here's one way to do it:

```
my $filename = 'path/to/sample_text';
open my $fh, '<', $filename
  or die "Can't open '$filename': $!";
chomp(my @strings = <$fh>);
while (1) {
  print 'Please enter a pattern: ';
  chomp(my $pattern = <STDIN>);
  last if $pattern =~ /\A\s*\Z/;
  my @matches = eval {
    grep /$pattern/, @strings;
  };
  if ($?) {
    print "Error: $@";
  } else {
    my $count = @matches;
    print "There were $count matching strings:\n",
      map "$_\n", @matches;
  }
  print "\n";
}
```

This one uses an `eval` block to trap any failure that might occur when using the regular expression. Inside that block, a `grep` pulls the matching strings from the list of strings.

Once the `eval` is finished, we can report either the error message or the matching strings. Note that we “unchomped” the strings for output by using `map` to add a newline to each string.

2. This program is simple. There are many ways that we can get a list of files, but since we only care about the ones in the current

working directory we can just use a `glob`. We use `foreach` to put each filename in the default variable `$_` since we know that `stat` uses that variable by default. We surround the entire `stat` before we perform the slice:

```
foreach ( glob( '*' ) ) {  
    my( $atime, $mtime ) = (stat)[8,9];  
    printf "%-20s %10d %10d\n", $_, $atime, $mtime;  
}
```

We know to use the indices 8 and 9 because we look at the documentation for `stat`. The documentation writers have been quite kind to us by showing us a table that maps the index of the list item to what it does, so we don't have to count over ourselves.

If we don't want to use `$_`, we can use our own control variable:

```
foreach my $file ( glob( '*' ) ) {  
    my( $atime, $mtime ) = (stat $file)[8,9];  
    printf "%-20s %10d %10d\n", $file, $atime, $mtime;  
}
```

3. This solution builds on the previous one. The trick now is to use `localtime` to turn the epoch times into date strings in the form `YYYY-MM-DD`. Before we integrate that into the full program, let's look at how we would do that, assuming that the time is in `$_` (which is the `map` control variable).

We get the indices for the slice from the `localtime` documentation:

```
my( $year, $month, $day ) = (localtime)[5,4,3];
```

We note that `localtime` returns the year minus 1900 and the month minus 1 (at least minus 1 how we humans count), so we

have to adjust that:

```
$year += 1900; $month += 1;
```

Finally, we can put it all together to get the format we want, padding the month and day with zeros if necessary:

```
sprintf '%4d-%02d-%02d', $year, $month, $day;
```

To apply this to a list of times, we use a map. Note that `localtime` is one of the operators that doesn't use `$_` by default, so you have to supply it as an argument explicitly:

```
my @times = map {  
    my( $year, $month, $day ) = (localtime($_))[5,4,3];  
    $year += 1900; $month += 1;  
    sprintf '%4d-%02d-%02d', $year, $month, $day;  
} @epoch_times;
```

This, then, is what we have to substitute in our `stat` line in the previous program, finally ending up with:

```
foreach my $file ( glob( '*' ) ) {  
    my( $atime, $mtime ) = map {  
        my( $year, $month, $day ) = (localtime($_))[5,4,3];  
        $year += 1900; $month += 1;  
        sprintf '%4d-%02d-%02d', $year, $month, $day;  
    } (stat $file)[8,9];  
  
    printf "%-20s %10s %10s\n", $file, $atime, $mtime;  
}
```

Most of the point of this exercise was to use the particular techniques we covered in [Chapter 16](#). There's another way to do

this, though, and it's much easier. The `POSIX` module, which comes with Perl, has a `strftime` subroutine that takes a `sprintf`-style format string and the time components in the same order that `localtime` returns them. That makes the map much simpler:

```
use POSIX qw(strftime);

foreach my $file ( glob( '*' ) ) {
    my( $atime, $mtime ) = map {
        strftime( '%Y-%m-%d', localtime($_) );
    } (stat $file)[8,9];

    printf "%-20s %10s %10s\n", $file, $atime, $mtime;
}
```

Appendix B. Beyond the Llama

We've covered a lot in this book, but there's even more. In this appendix, we'll tell you a little more about what Perl can do, and give some references on where to learn the details. Some of what we mention here is on the bleeding edge and may have changed by the time you're reading this book, which is one reason we frequently send you to the documentation for the full story. We don't expect many readers to read every word of this appendix, but we hope you'll at least skim the headings so that you'll be prepared to fight back when someone tells you, "You just can't use Perl for project X because Perl can't do Y."

The most important thing to keep in mind (so that we're not repeating it in every paragraph) is that the most important part of what we're *not* covering here is covered in *Intermediate Perl*, also known as "the Alpaca." You should definitely read the Alpaca, especially if you'll be writing programs that are longer than 100 lines (either alone or with other people). Especially if you're tired of hearing about Fred and Barney and want to move on to another fictional universe featuring seven people who got to spend a lot of time on an isolated island after a cruise!

After *Intermediate Perl*, you'll be ready to move on to *Mastering Perl*, also known as "the Vicuña." It covers the everyday tasks that you'll want to do while programming Perl, such as benchmarking and profiling, program configuration, and logging. It also goes through the work you'll need to do to deal with code written by other people and how to integrate that into your own applications.

In *Perl New Features*, brian covers the features added to Perl starting with v5.10 up to the current version. As an ebook, it's easy to update this book for new versions of Perl.

There are many other good books to explore. Depending on your version of Perl, look in either *perlfaq2* or *perlbook* for many recommendations,

especially before you spend your money on a book that might be rubbish or out of date.

Further Documentation

The documentation that comes with Perl may seem overwhelming at first. Fortunately, you can use your computer to search for keywords in the documentation. When searching for a particular topic, it's often good to start with the [perltoc](#) (table of contents) and [perlfaq](#) (frequently asked questions) sections. On most systems, the *perldoc* command should be able to track down the documentation for Perl, installed modules, and related programs (including *perldoc* itself). You can read the same [documentation online](#), although that is always for the latest version of Perl.

Regular Expressions

Yes, there's even more about regular expressions than we mentioned. *Mastering Regular Expressions* by Jeffrey Friedl is one of the best technical books we've ever read. It's half about regular expressions in general, and half about Perl's regular expressions, which many other languages incorporate as Perl-Compatible Regular Expressions (PCRE). It goes into great detail about how the regular expression engine works internally, and why one way of writing a pattern may be much more efficient than another. Anyone who is serious about Perl should read this book. Also see the [perlre documentation](#) (and its companion [perlretut](#) and [perlrequick](#) in newer versions of Perl). And there's more about regular expressions in *Intermediate Perl* and *Mastering Perl* as well.

Packages

Packages allow you to compartmentalize namespaces. Imagine that you have 10 programmers all working on one big project. If someone uses the global names `$fred`, `@barney`, `%betty`, and `&wilma` in their part of

the project, what happens when you accidentally use one of those same names in your part? Packages let you keep them separate; I can access your `$fred`, and you can access mine, but not by accident. You need packages to make Perl scalable so that you can manage large programs. We cover packages in great detail in *Intermediate Perl*.

Extending Perl's Functionality

One of the most common pieces of good advice heard in the Perl discussion forums is that you shouldn't reinvent the wheel. Other folks have written code that you can put to use. The most frequent way to add to what Perl can do is by using a library or module. Many of these come with Perl, while others are available from CPAN. Of course, you can even write your own libraries and modules.

Modules such as `Inline::C` allow you to easily hook up C code to Perl.

Writing Your Own Modules

In the rare case that there's no module to do what you need, you can write a new one, either in Perl or in another language (often C). *Intermediate Perl* covers how to write, test, and distribute modules.

Databases

If you've got a database, Perl can work with it. We've already seen the DBI module briefly in *Chapter 11*.

Perl can directly access some system databases, sometimes with the help of a module. These are databases like the Windows Registry (which holds machine-level settings), or the Unix password database (which lists which username corresponds to which number, and related information), as well as the domain-name database (which lets you translate an IP number into a machine name, and vice versa).

Mathematics

Perl can do just about any kind of mathematics you can dream up. The `PDL` module (for Perl Data Language) provides high-powered ways to do tricky math.

All of the basic mathematical functions (square root, cosine, logarithm, absolute value, and many others) are available as built-in functions; see the [perlfunc documentation](#) for details. Some others (like tangent or base-10 logarithm) are omitted, but those may be easily created from the basic ones, or loaded from a simple module that does so. (See the `POSIX` module for many common math functions.)

Although the core of Perl doesn't directly support complex numbers, there are modules available for working with them. These overload the normal operators and functions so that you can still multiply with `*` and get a square root with `sqrt`, even when using complex numbers. See the `Math::Complex` module.

You can do math with arbitrarily large numbers with an arbitrary number of digits of accuracy. For example, you could calculate the factorial of two thousand, or determine π to ten-thousand digits. See the `Math::BigInt` and `Math::BigFloat` modules.

Lists and Arrays

Perl has a number of features that make it easy to manipulate an entire list or array.

In [Chapter 16](#), we mentioned the `map` and `grep` list-processing operators. They can do more than we could include here; see the [perlfunc documentation](#) for more information and examples. And check out *Intermediate Perl* for more ways to use `map` and `grep`.

Bits and Pieces

You can work with an array of bits (a `bitstring`) with the `vec` operator, setting bit number 123, clearing bit number 456, and checking to see the state of bit 789. Bitstrings may be of arbitrary size. The `vec` operator can also work with chunks of other sizes, as long as the size is a small power of two, so it's useful if you need to view a string as a compact array of nybbles, say. See the [perlfunc documentation](#) or *Mastering Perl*.

Formats

Perl's formats are an easy way to make fixed-format, template-driven reports with automatic page headers. In fact, they are one of the main reasons Larry developed Perl in the first place: as a Practical Extraction and *Report* Language. But, alas, they're limited. The heartbreak of formats happens when someone discovers that they need a little more than what formats provide. This usually means ripping out the program's entire output section and replacing it with code that doesn't use formats. Still, if you're sure that formats do what you need, *all* that you'll need, and all that you'll *ever* need, they are pretty cool. See the [perlform documentation](#).

Networking and IPC

If there's a way that programs on your machine can talk with other programs, Perl can probably do it. This section shows some common ways.

System V IPC

All of the standard functions for System V IPC (interprocess communication) are supported by Perl, so you can use message queues, semaphores, and shared memory. Of course, an array in Perl isn't stored in a chunk of memory in the same way that an array is stored in C, so shared memory can't share Perl data as is. But there are modules that will translate data so that you can pretend your Perl data is in shared memory. See the [perlfunc](#) and the [perlipc documentation](#).

Sockets

Perl has full support for TCP/IP sockets, which means you could write a web server in Perl, or a web browser, Usenet news server or client, finger daemon or client, FTP daemon or client, SMTP or POP or SOAP server or client, or either end of pretty much any other kind of protocol in use on the internet. You'll find low-level modules for these in the `Net::` namespace, and many of them come with Perl.

Of course, there's no need to get into the low-level details yourself; there are modules available for all of the common protocols. For example, you can make a web server or client with the `LWP`, `WWW::Mechanize`, or `Mojoc::UserAgent` modules.

Security

Perl has a number of strong, security-related features that can make a program written in Perl more secure than the corresponding program written in C. Probably the most important of these is data-flow analysis, better known as *taint checking*. When this is enabled, Perl keeps track of which pieces of data seem to have come from the user or environment (and are therefore untrustworthy). Generally, if any such piece of so-called “tainted” data is used to affect another process, file, or directory, Perl will prohibit the operation and abort the program. It's not perfect, but it's a powerful way to prevent some security-related mistakes. There's more to the story; see the [perlsec documentation](#) or *Mastering Perl*.

Debugging

There's a very good debugger that comes with Perl and supports breakpoints, watchpoints, single-stepping, and generally everything you'd want in a command-line Perl debugger. It's actually written in Perl (so if there are bugs in the debugger, we're not sure how they get those out). But that means that, in addition to all the usual debugger commands, you can

actually run Perl code from the debugger—calling your subroutines, changing variables, even redefining subroutines—while your program is running. See the [perldebug documentation](#) for the latest details.

Intermediate Perl gives a detailed walkthrough of the debugger.

Another debugging tactic is to use the `B::Lint` module, which can warn you about potential problems that even the `-w` switch misses.

Command-Line Options

There are many different command-line options available in Perl; many let you write useful programs directly from the command line. See the [perlrun documentation](#).

Built-in Variables

Perl has dozens of built-in variables (like `@ARGV` and `$0`), which provide useful information or control the operation of Perl itself. See the [perlvar documentation](#).

References

Perl’s references are similar to C’s pointers, but in operation, they’re more like what you have in Pascal or Ada. A reference “points” to a memory location, but because there’s no pointer arithmetic or direct memory allocation and deallocation, you can be sure that any reference you have is a valid one. References allow object-oriented programming and complex data structures, among other nifty tricks. See the [perlreftut](#) and [perlref documentation](#). *Intermediate Perl* covers references in great detail.

Complex Data Structures

References allow you to make complex data structures in Perl. For example, suppose you want a two-dimensional array. You can do that, or you can do

something much more interesting, like have an array of hashes, a hash of hashes, or a hash of arrays of hashes. See the [perldsc \(data-structures cookbook\)](#) and [perllool \(lists of lists\) documentation](#). Again, *Intermediate Perl* covers this quite thoroughly, including techniques for complex data manipulation, like sorting and summarizing.

Object-Oriented Programming

Yes, Perl has objects; it's buzzword compatible with all of those other languages. Object-oriented (OO) programming lets you create your own user-defined datatypes with associated abilities, using inheritance, overriding, and dynamic method lookup. Unlike some object-oriented languages, though, Perl doesn't force you to use objects.

If your program is going to be larger than N lines of code, it may be more efficient (if a tiny bit slower at runtime) for the programmer to make it object oriented. No one knows the precise value of N, but we estimate it's around a few thousand or so. See the [perlobj](#) and [perloutut documentations](#) for a start, and Damian Conway's excellent *Object Oriented Perl* (Manning Press) for more advanced information. *Intermediate Perl* covers objects thoroughly as well.

As we write this, the Moose meta-object system is very popular in Perl. It sits atop the bare-metal Perl objects to provide a much nicer interface.

Anonymous Subroutines and Closures

Odd as it may sound at first, it can be useful to have a subroutine without a name. Such subroutines can be passed as parameters to other subroutines, or they can be accessed via arrays or hashes to make jump tables. Closures are a powerful concept that comes to Perl from the world of Lisp. A closure is (roughly speaking) an anonymous subroutine with its own private data. Again, we cover these in *Intermediate Perl* and in *Mastering Perl*.

Tied Variables

A tied variable may be accessed like any other, but uses your own code behind the scenes. So you could make a scalar that is really stored on a remote machine, or an array that always stays sorted. See the [perltie documentation](#) or *Mastering Perl*.

Operator Overloading

You can redefine operators like addition, concatenation, comparison, or even the implicit string-to-number conversion with the `overload` module. This is how a module implementing complex numbers (for example) can let you multiply a complex number by 8 to get a complex number as a result.

Using Other Languages Inside Perl

Through the `Inline` modules, you can embed C and other languages inside a Perl program. The module takes care of connecting the external language to your Perl program in a seamless way that you won't notice. This is especially handy when a vendor provides a library in another language but you want to use Perl.

Embedding

The reverse of dynamic loading (in a sense) is embedding.

Suppose you want to make a really cool word processor, and you start writing it in (say) C++. Now you decide you want your users to be able to use Perl's regular expressions for an extra-powerful search-and-replace feature, so you embed Perl into your program. Then you realize that you could open up some of the power of Perl to your users. A power user could write a subroutine in Perl that could become a menu item in your program. Users can customize the operation of your word processor by writing a little Perl. Now you open up a little space on your website where users can share and exchange these Perl snippets, and you've got thousands of new programmers extending what your program can do at no extra cost to your

company. And how much do you have to pay Larry for all this? Nothing—see the licenses that came with Perl. Larry is a really nice guy. You should at least send him a thank-you note.

Although we don't know of such a word processor, some folks have already used this technique to make other powerful programs. One such example is Apache's `mod_perl`, which embeds Perl into an already-powerful web server. If you're thinking about embedding Perl, you should check out `mod_perl`; since it's all open source, you can see how it works.

Converting find Command Lines to Perl

A common task for a system administrator is to recursively search the directory tree for certain items. On Unix, this is typically done with the *find* command. We can do that directly from Perl too.

The *find2perl* command, which comes with Perl up to v5.20 (and in `App::find2perl` now), takes the same arguments that *find* does. Instead of finding the requested items, however, the output of *find2perl* is a Perl program that finds them. Since it's a program, you can edit it for your own needs.

One useful argument that's available in *find2perl* but not in the standard *find* is the `-eval` option. This says that what follows it is actual Perl code that should be run each time that a file is found. When it's run, the current directory will be the directory in which some item is found, and `$_` will contain the item's name.

Here's an example of how you might use *find2perl*. Suppose that you're a system administrator on a Unix machine, and you want to find and remove all the old files in the */tmp* directory. Here's the command that writes the program to do that:

```
$ find2perl /tmp -atime +14 -eval unlink >Perl-program
```

That command says to search in */tmp* (and recursively in subdirectories) for items whose `atime` (last access time) is at least 14 days ago. For each item, the program should run the Perl code `unlink`, which will use `$_` by default as the name of a file to remove. The output (redirected to go into the file *Perl-program*) is the program that does all of this. Now you merely need to arrange for it to be run as needed.

Command-Line Options in Your Programs

If you'd like to make programs that take command-line options (like Perl's own `-w` for warnings, for example), there are modules that let you do this in a standard way. See the documentation for the `Getopt::Long` and `Getopt::Std` modules.

Embedded Documentation

Perl's own documentation is written in *pod* (plain-old documentation) format. You can embed this documentation in your own programs, and it can then be translated to text, HTML, or many other formats as needed. See the [perlpod documentation](#). *Intermediate Perl* covers this too.

More Ways to Open Filehandles

There are other modes to use in opening a filehandle; see the [perlopentut documentation](#). The `open` built-in is so feature-full that it gets its own documentation page.

Graphical User Interfaces (GUIs)

There are several GUI toolkits with Perl interfaces. See CPAN for `Tk`, `Wx`, and others.

And More...

If you check out the module list on CPAN, you'll find modules for even more purposes, from generating graphs and other images to downloading email, from figuring the amortization of a loan to figuring the time of sunset. New modules are added all the time, so Perl is even more powerful today than it was when we wrote this book. We can't keep up with it all, so we'll stop here.

Appendix C. A Unicode Primer

This isn't a complete or comprehensive introduction to Unicode; it's just enough for you to understand the parts of Unicode that we present in this book. Unicode is tricky not only because it's a new way to think about strings, with lots of adjusted vocabulary, but also because computer languages in general have implemented it so poorly. Each version since v5.6 has brought Perl closer to full compliance. Perl has, arguably, the best Unicode support that you will find, though.

Unicode

The Universal Character Set (UCS) is an abstract mapping of *characters* to *code points*. It has nothing to do with a particular representation in memory, which means we can agree on at least one way to talk about characters no matter which platform we're on. An *encoding* turns the code points into a particular representation in memory, taking the abstract mapping and representing it physically within a computer. You probably think of this storage in terms of bytes, although when talking about Unicode, we use the term *octets* (see [Figure C-1](#)). Different encodings store the characters differently. To go the other way, interpreting the octets as characters, you *decode* them. You don't have to worry too much about these because Perl can handle most of the details for you.

When we talk about a code point, we specify its number in hexadecimal like so: (U+0158); that's the character Ř. Code points also have names, and that code point is "LATIN CAPITAL LETTER R WITH CARON." Not only that, but code points know certain things about themselves. They know if they are an uppercase or lowercase character, a letter or digit or whitespace, and so on. They know what their uppercase, title case, or lowercase partner is, if appropriate. This means that not only can we work with the particular characters, but we now have a way to talk about *types* of

characters. All of this is defined in Unicode datafiles that come with *perl*. Look for a *unicore* directory in your Perl library directory; that's how Perl knows everything it needs to know about characters.

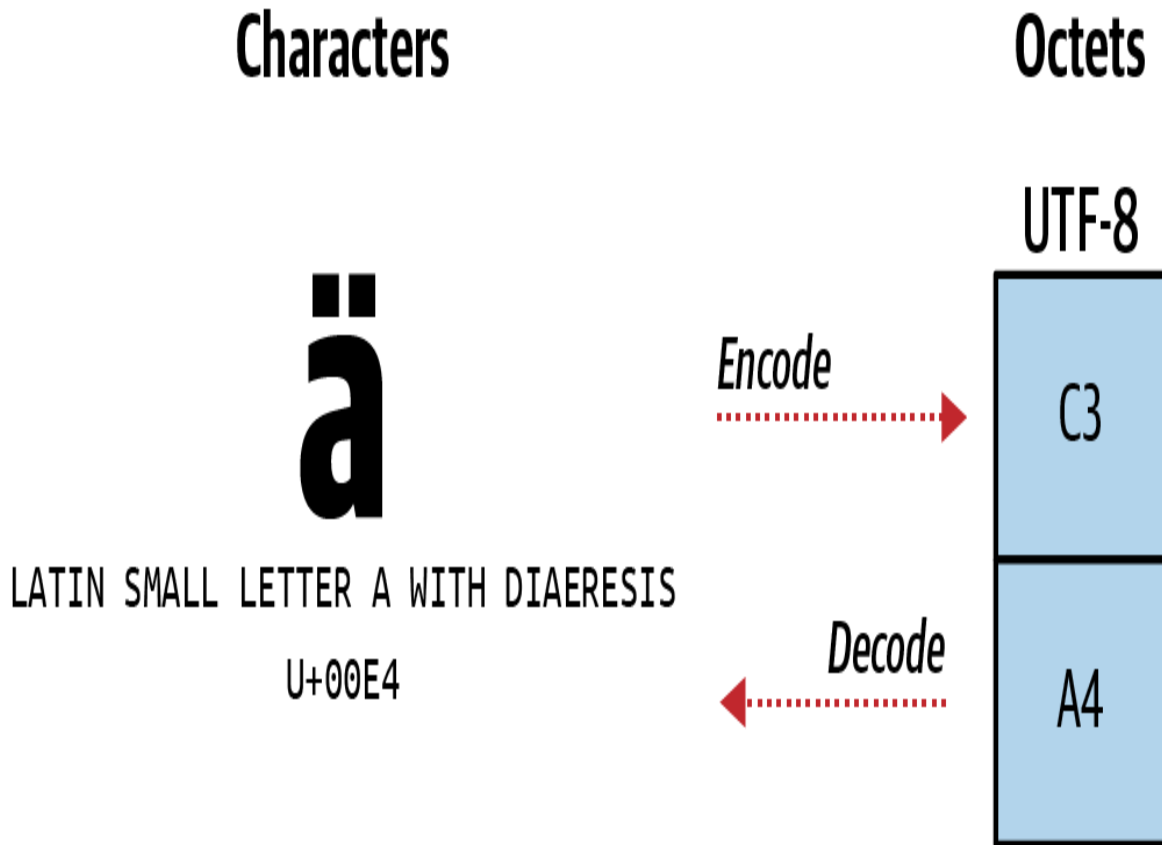


Figure C-1. The code point of a character is not its storage. The encoding transforms characters into storage.

UTF-8 and Friends

The preferred encoding in Perl is UTF-8, which is short for UCS Transformation Format 8-bit. Rob Pike and Ken Thompson defined this encoding one night on the back of a paper placemat in a New Jersey diner. It's just one possible encoding, although a very popular one since it doesn't have the drawbacks of some other encodings. If you're using Windows, you're likely to run into UTF-16. We don't have anything nice to say about that encoding, so we'll just keep quiet like our mothers told us.

NOTE

Read about the [invention of UTF-8 from Rob Pike himself](#).

Getting Everyone to Agree

Getting everything set up to use Unicode can be frustrating because every part of the system needs to know which encoding to expect so it can display it properly. Mess up on any part of that and you might see gibberish, with no clue which part isn't working correctly. If your program outputs UTF-8, your terminal needs to know that so it displays the characters correctly. If you input UTF-8, your Perl program needs to know that so it interprets the input strings correctly. If you put data into a database, the database server needs to store it correctly and return it correctly. You have to set up your editor to save your source in UTF-8 if you want *perl* to interpret your typing as UTF-8.

We don't know which terminal you are using and we're not going to list instructions for every (or any) terminal here. For modern terminal programs, you should find a setting in the preferences or properties for the encoding.

Beyond the encoding, various programs need to know how to output the encoding that you want. Some look at the `LC_*` environment variables and some have their own:

```
LESSCHARSET=utf-8
LC_ALL=en_US.UTF-8
```

If something is not displaying correctly through your pager (i.e., less, more, type), read their documentation to see what they expect you to set to give encoding hints.

Fancy Characters

Thinking in Unicode requires a different mindset if you are used to ASCII. For instance, what's the difference between *é* and *é*? You probably can't tell just by looking at those, and even if you have the digital version of this book, the publication process might have "fixed" the difference. You might not even believe us that there is a difference, but there is. The first one is a single character but the second one is two characters. How can that be? To humans, those are the same thing. To us, they are the same *grapheme* (or *glyph*) because the idea is the same no matter how the computer deals with either of them. We mostly care about the end result (the grapheme) since that's what imparts information to our readers.

Before Unicode, common character sets defined characters such as *é* as an atom, or single entity. That's the first of our examples in the previous paragraph (just trust us). However, Unicode also introduces the idea of *mark* characters—the accents and other flourishes and annotations that combine with another character (called *nonmarks*). That second *é* is actually the nonmark character *e* (U+0065, LATIN SMALL LETTER E) and the mark character *'* (U+0301, COMBINING ACUTE ACCENT) that is the pointy part over the letter. These two characters together make up the grapheme. Indeed, this is why you should stop calling the overall representation a character and call it a grapheme instead. One or more characters can make up the final grapheme. It's a bit pedantic, but it makes it much easier to discuss Unicode without going insane.

If the world were starting fresh, Unicode probably wouldn't have to deal with the single-character version of *é*, but the single-character version exists historically, so Unicode does handle it to be somewhat backward compatible and friendly with the text that's already out there. Unicode code points have the same ordinal values for the ASCII and Latin-1 encodings, which are all the code points from 0 to 255. That way, treating your ASCII strings as UTF-8 should work out just fine (but not UTF-16, where every character takes up at least two bytes).

The single-character version of *é* is a *composed* character because it represents two (or more) characters as one code point. It composes the nonmark and mark into a single character (U+00E9, LATIN SMALL

LETTER E WITH ACUTE) that has its own code point. The alternative is the *decomposed* version that uses two characters.

So, why do you care? How can you properly sort text if what you think of as the same thing is actually different characters? Perl's `sort` cares about characters, not graphemes, so the strings `"\x{E9}"` and `"\x{65}\x{301}"`, which are both logically *é*, do not sort to the same position. Before you sort these strings, you want to ensure that both *é*'s sort next to each other no matter how you represent them. Computers don't sort in the same way that humans want to sort items. You don't care about composed or decomposed characters. We'll show you the solution in a moment, and you should check [Chapter 14](#).

Using Unicode in Your Source

If you want to have literal UTF-8 characters in your source code, you need to tell *perl* to read your source as UTF-8. You do that with the `utf8` pragma, whose only job is to tell *perl* how to interpret your source. This example has Unicode characters in a string:

```
use utf8;

my $string = "Here is my 🇫🇷 résumé";
```

You can also use some characters in variable and subroutine names:

```
use utf8;

my %résumés = (
    Fred => 'fred.doc',
    ...
);

sub π () { 3.14159 }
```

The only job of the `utf8` pragma is to tell *perl* to interpret your source code as UTF-8. It doesn't do anything else for you. As you decide to work

with Unicode, it's a good idea to always include this pragma in your source unless you have a good reason not to.

NOTE

Typing characters you don't see on your keyboard may be difficult. Services such as [r12a's Unicode code converter](#) and [UniView 9.0.0](#) or a program such as [UnicodeChecker](#) can help.

Fancier Characters

It gets worse, though, although not as many of you probably care about this one. What's the difference between *fi* and *fi*? Unless the typesetter “optimized” this, the first one has the *f* and the *i* separated while the second one combines those in a *ligature*, which generally sets the graphemes in a way that makes it easier for people to read. The overhanging part of the *f* appears to impose on the personal space of the dot on the *i*, which is a bit ugly. We don't actually read each letter in a word and instead recognize it as a whole; the ligature is a slight improvement in our pattern recognition. So typographers combine the two graphemes. You may have never noticed it, but you'll find several examples in this paragraph, and you'll find them often in typeset books (but usually not ebooks, which typically don't care as much about looking nice).

NOTE

O'Reilly's automated typesetting system doesn't turn our *fi*'s into their ligature forms unless we type the ligatures ourselves. It's probably a faster document workflow that way, even if we do have to shuffle some graphemes manually. Fingers crossed that it shows up the way we wanted!

The difference is similar to the composed and decomposed forms of *é*, but slightly different. The *é*'s were *canonically equivalent* because no matter which way you made it, the result was the same visual appearance and the same idea. The *fi* and *fi* don't have the same visual appearance, so they are merely *compatibility equivalent*. You don't need to know too much about

that other than knowing that you can decompose both canonically and compatibility equivalent forms to a common form that you can use to sort (Figure C-2). See Unicode Standard Annex #15, “Unicode Normalization Forms” for the gory details.

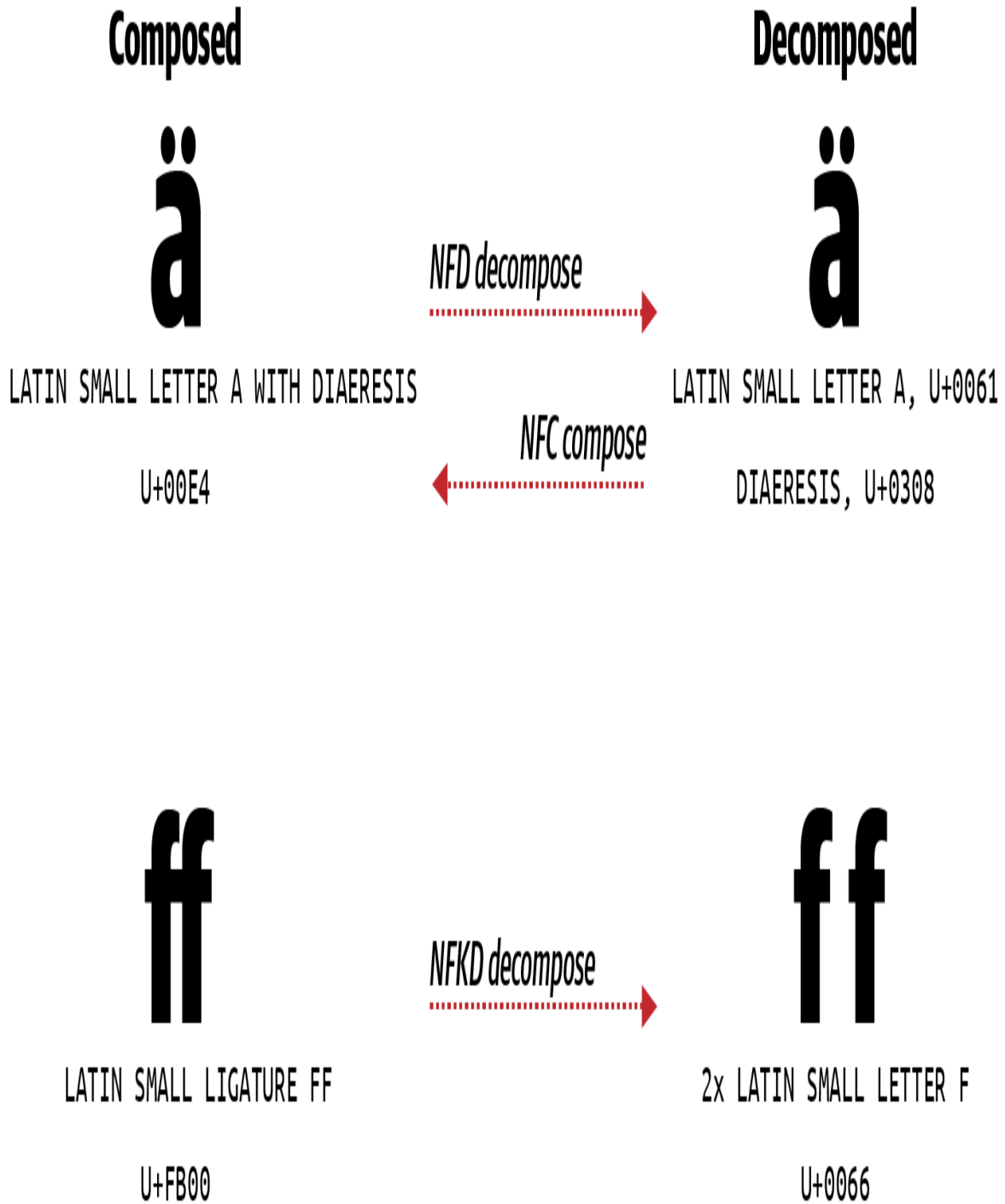


Figure C-2. You can decompose and recompose canonical equivalent forms, but you can only decompose compatible forms.

Suppose that you want to check if a string has an *é* or an *fi* and you don't care about which form it has. To do that, you decompose the strings to get them in a common form. To decompose Unicode strings, use the

Unicode::Normalize module, which comes with Perl. It supplies two subroutines for decomposition. You use the NFD subroutine (*Normalization Form Decomposition*), which turns canonically equivalent forms into the same decomposed form. You use the NFKD subroutine (*Normalization Form Kompatibility Decomposition*) to convert to compatible forms that represent the same thing but aren't the same thing (for example, *ss* for *ß*). This example has a string with composed characters that you decompose and match in various ways. The “oops” messages shouldn't print, while the “yay” messages should:

```
use utf8;
use Unicode::Normalize;

# U+FB01          - fi ligature
# U+0065 U+0301   - decomposed é
# U+00E9          - composed é

binmode STDOUT, ':utf8';

my $string =
    "Can you \x{FB01}nd my r\x{E9}sum\x{E9}?" ;

if( $string =~ /\x{65}\x{301}/ ) {
    print "Oops! Matched a decomposed é\n";
}
if( $string =~ /\x{E9}/ ) {
    print "Yay! Matched a composed é\n";
}

my $nfd = NFD( $string );
if( $nfd =~ /\x{E9}/ ) {
    print "Oops! Matched a composed é\n";
}
if( $nfd =~ /fi/ ) {
    print "Oops! Matched a decomposed fi\n";
}

my $nfkd = NFKD( $string );
if( $string =~ /fi/ ) {
    print "Oops! Matched a decomposed fi\n";
}
if( $nfkd =~ /fi/ ) {
    print "Yay! Matched a decomposed fi\n";
}
```

```

}
if( $nfkd =~ /\x{65}\x{301}/ ) {
    print "Yay! Matched a decomposed é\n";
}

```

As you can see, the NFKD forms always match the decompositions because `NFKD()` decomposes both canonical and compatible equivalents. The NFD forms miss the compatible equivalents:

```

Yay! Matched a composed é
Yay! Matched a decomposed fi
Yay! Matched a decomposed é

```

There's a caution here, though: you can decompose and recompose canonical forms, but you cannot necessarily recompose compatible forms. If you decompose the ligature *fi*, you get the separate graphemes *f* and *i*. The recomposer has no way to know if those came from a ligature or started separately. (This is why we're ignoring NFC and NFKC. Those forms decompose then recompose, but NFKC can't necessarily recompose to the original form.) Again, that's the difference in canonical and compatible forms: the canonical forms look the same either way.

Dealing with Unicode in Perl

This section is a quick summary of the most common ways you'll incorporate Unicode into your Perl programs. This is not a definitive guide, and even for the things we do show there are some details that we ignore. It's a big subject, and we don't want to scare you off. Learn a little at first (this appendix), but when you run into problems, reach for the detailed documentation we list at the end of the appendix.

Fancier Characters by Name

Unicode characters also have names. If you can't easily type the character with your keyboard and you can't easily remember the code points, you can use its name (although it is a lot more typing). The `chardnames` pragma,

which comes with Perl, gives you access to those names. Put the name inside `\N{ . . . }` in a double-quotish context:

```
my $string = "\N{THAI CHARACTER KHOMUT}"; # U+0E5B
```

Note that the pattern portions of the match and substitution operators are also double-quoted context, but there's also a character class shortcut `\N` that means “not a newline” (see [Chapter 8](#)). It usually works out just fine because there are only some weird cases where Perl might get confused. For a detailed discussion of the `\N` problem, see the blog post “[Use the /N regex character class to get ‘not a newline’](#)” for more information.

Reading from STDIN or Writing to STDOUT or STDERR

At the lowest level, your input and output is just octets. Your program needs to know how to decode or encode them. We've mostly covered this in [Chapter 5](#), but here's a summary.

You have two ways to use a particular encoding with a filehandle. The first one uses `binmode`:

```
binmode STDOUT, ':encoding(UTF-8)';
binmode $fh, ':encoding(UTF-16LE)';
```

You can also specify the encoding when you open the filehandle:

```
open my $fh, '>:encoding(UTF-8)', $filename;
```

If you want to set the encoding for all filehandles that you will open, you can use the `open` pragma. You can affect all input or all output filehandles:

```
use open IN => ':encoding(UTF-8)';
use open OUT => ':encoding(UTF-8)';
```

You can do both with a single pragma:

```
use open IN => ":crlf", OUT => ":bytes";
```


If you want to use the same encoding for both input and output, you can set them at the same time, either using `IO` or omitting it:

```
use open IO => ":encoding(iso-8859-1)";
use open ':encoding(UTF-8)';
```

Since the standard filehandles are already open, you can apply your previously stated encoding by using the `:std` subpragma:

```
use open ':std';
```

This last one has no effect unless you've already explicitly declared an encoding. In that case, add the encoding as the second import item:

```
use open qw(:std :encoding(UTF-8));
```

You can also set these on the command line with the `-C` switch, which will set the encodings on the standard filehandles according to the arguments you give to it:

I	1	STDIN is assumed to be in UTF-8
O	2	STDOUT will be in UTF-8
E	4	STDERR will be in UTF-8
S	7	I + O + E
i	8	UTF-8 is the default PerlIO layer for input streams
o	16	UTF-8 is the default PerlIO layer for output streams
D	24	i + o

See the [perlrun documentation](#) for more information about command-line switches, including the details for `-C`.

Reading from and Writing to Files

We cover this in [Chapter 5](#), but here's the summary. When you open a file, use the three-argument form and specify the encoding so you know exactly what you are getting:

```
open my( $read_fh ),    '<:encoding(UTF-8)', $filename;
open my( $write_fh ),   '>:encoding(UTF-8)', $file_name;
open my( $append_fh ), '>>:encoding(UTF-8)', $file_name;
```

Remember, though, that you don't get to pick the encoding of the input (at least not from inside your program). Don't choose an encoding for the input unless you are sure that's the encoding the input actually is. Notice that although you're really *decoding* input, you still use `:encoding`.

If you don't know what sort of input you'll get (and one of the Laws of Programming is that run enough times, you'll see every possible encoding), you can also just read the raw stream and guess the encoding, perhaps with `Encode::Guess`. There are many gotchas there, though, and we won't go into them here.

Once you get the data into your program, you don't need to worry about the encoding anymore. Perl stores it smartly and knows how to manipulate it. It's not until you want to store it in a file (or send it down a socket, and so on) that you need to encode it again.

Dealing with Command-Line Arguments

As we have said before, you need to be careful about the source of any data when you want to treat it as Unicode. The `@ARGV` array is a special case since it gets its values from the command line, and the command line uses the locale:

```
use I18N::Langinfo qw(langinfo CODESET);
use Encode qw(decode);

my $codeset = langinfo(CODESET);

foreach my $arg ( @ARGV ) {
    push @new_ARGV, decode $codeset, $arg;
}
```

Dealing with Databases

Our editor tells us that we are running out of space, and it's almost the end of the book! We don't have that much space to cover this topic, but that's OK because it's not really about Perl. Still, he's allowing us a couple of sentences. It's really too bad that we can't go into all the ways that database servers make life so hard, or how they all do it in different ways.

Eventually you'll want to store some of your information in a database. The most popular Perl module for database access, DBI, is Unicode-transparent, meaning it passes the data it gets directly to the database server without messing with it. Check its various drivers (for example, `DBD::mysql`) to see which driver-specific settings you'll need. You also have to set up your database server, schemas, tables, and columns correctly. Now you can see why we're glad we've run out of space!

Further Reading

There are several parts of the Perl documentation that will help you with the language-specific parts, including the [perlunicode](#), [perlunifaq](#), [perluniintro](#), [perluniprops](#), and [perlunitut documentation](#). Don't forget to check the documentation for any of the Unicode modules that you use.

The official [Unicode site](#) has almost everything you'd ever want to know about Unicode, and is a good place to start.

There's also a Unicode chapter in *Effective Perl Programming* (Addison-Wesley), also by one of the authors of this book.

Appendix D. Experimental Features

You can completely skip this appendix and the experimental features we show and not suffer for it. Or you can blindly follow the examples we show in the chapters and not worry about what is happening. But we think you'll want to use them and understand them because we want to use and understand them too.

Many of the new features in Perl aren't really "new." They're *experimental*. You have to do something to enable them, they might change, and they might disappear altogether. In fact, v5.24 removed two experimental features.

This is quite clever. People can install the latest *perl* and start using these new features. They can test them, see how they interact with other features, and best of all, develop unexpected idioms for them. Or they can completely ignore them and not worry about backward compatibility. The Perl 5 Porters, the people who develop and maintain the Perl code base, get to see how people use and react to a feature before they commit to making it permanent.

Learning Perl should show you the best and most exciting ways of working in Perl, but we also don't want you to rely on experimental features that might disappear a year after you buy this book. We show you some of the new features, but when we do, we point to this appendix so you can get the background we don't want to explain each time.

The `feature` module documentation lists most of the new features and gives a brief description of their use. You can also read the [perldelta documentation](#) in each release of Perl to learn about new developments. We show the state of most new features in [Table D-1](#). Before we tell you about that, we give you some background.

A Short History of Perl Development

Perl has gone through several eras of development, each with its own story. Knowing what's come before can help you appreciate where Perl is now.

In the late 1980s, Larry Wall created the Perl language (although that was not the first name he tried to use). He mostly worked on his own with some feedback from the Usenet community. Kids today probably have never seen a newsgroup, but it was the social media of the time, and that's where he first released Perl in 1987.

Eventually Perl was interesting enough to have books about it (this book in particular, and *Programming perl*, with pink covers before our publisher moved Perl books to blue covers). Perl was promoted to version 4. That's also around the time Perl's popularity exploded, and when many people learned (or stopped learning) Perl. Quite frankly, it's this era that set most of the world's expectations of Perl, and more disappointedly, Perl programmers. But that's spilt milk.

But Perl 4 didn't have object-oriented features, good ways to make complex data structures, or lexical scoping. Around 1993, Larry started working on Perl 5, the current major version and the one we write about in this book.

To move from Perl 4 to Perl 5, a gang of Perlers created the Perl 5 Porters to ensure that Perl 5 was ported to hundreds of different platforms. Today the group is still there, although the people have changed. You can read more about their process in [perlpolicy](#).

The [perlhlist documentation](#) lists each Perl release, including its date and maintainer. After Larry released Perl 5.0 in 1994, other people took responsibility for some releases. After a new version release, other people typically came in to maintain the old version. It was a bit haphazard and ad hoc, but it worked for a while.

The Porters made big changes in Perl 5.6, and again in Perl 5.8. Perl was going through some growing pains, including the switch to handling Unicode. From Perl 5.004 to 5.005 was a little over a year, but from 5.005 to 5.6 was almost two years. The lag time from Perl 5.6 to 5.8 was over two years. However, the time between releases was increasing.

NOTE

Notice how differently we write the version numbers between 5.005 and v5.6. A Perler who has been around for a while will say “five double-oh five” but “five point six” for those. We started talking about the second (or *minor*) number as the release version. It's a quirk of history.

After Perl 5.8, people knew the code needed drastic changes for continued development. Chip Salzenberg tried rewriting Perl in C++ in a secret project he had dubbed “Topaz.” It didn't work out, although he learned interesting lessons in the process. Around the same time, Larry and a few others had the idea to start Perl 6, a complete rewrite of the code base to allow easier development and modern features.

Perl 5.10 and Beyond

Now we're going to ignore half of the fork that happens at this point, and rather than spark historical debates, we'll merely write that Perl 6 (now called “Raku”) did not become the next major version of Perl. It became a mostly separate language in its own right, but that's another book, [Learning Perl 6](#). For a few years it did distract some people from Perl 5 development, but then, suddenly, Perl 5 resuscitated itself. At the end of 2007, over five years since the previous Perl 5 release, Rafael Garcia-Suarez released v5.10. This release had some features stolen from the ongoing Perl 6 development, mostly `say` ([Chapter 5](#)), `state` ([Chapter 4](#)), `given-when`, and smart matching (those last two are experimental features we have since removed from this book).

Larry had moved on to Perl 6 development. For the first time, Larry was not in charge of Perl 5 development. Jesse Vincent stepped up to take on that role and started putting a post-Larry

process in order, including a regular release cycle for development versions and yearly releases for stable versions.

Ricardo Signes later took over for Jesse and put more policies into place. New features would start as “experimental” features until they had proven themselves. After two stable releases, a new feature could move to a permanent feature. These experimental features won’t disturb your program if you don’t enable them, so you have backward compatibility at the same time. Or you can enable them at your own risk if you want to play with the latest stuff.

The Perl 5 Porters applied the same process to removing features. Perl has several warts (admit it, we all know it does) and a list of deprecated features and variables. Did you know that there was a variable to control the starting index of an array? You didn’t? Don’t worry, it’s gone now (but it’s not, because there’s an experimental feature that restores it). Through the new process, Perl marks a feature deprecated and warns about its use. After two stable releases (so, two years), the Porters could remove the feature safe in the knowledge that they’d given abundant warnings. And they are actually removing features now. They still support backward compatibility, but within reason.

NOTE

You can read the official Perl support policy in [perlpolicy](#). Basically, the Porters offer official support for the previous two stable releases. If v5.34 is the latest release, they support v5.34 and v5.32 officially. They might update v5.30 or some other earlier version at their discretion.

Suppose you have something that needs the old features. What do you do? Simple—keep the old *perl* around! It’s the same *perl* you’ve been using for years and no one is taking it away from you. Oh, you are using the system *perl* and your system wants to upgrade it? Well, now you know one of the reasons you shouldn’t rely on the system *perl*. That’s for the system, not you! Install your own *perl* for your important applications.

NOTE

Installing your own *perl* not only guards you from the whims of your system upgrades, but it can also be faster. The system *perl* isn’t tuned for your use. It’s compiled to be the least hassle for everyone. If you don’t want features such as debugging systems or threads, you can compile your own *perl* without those for a small speedup. You could even compile another *perl* with those features.

Installing a Recent Perl

Before you think about installing a new Perl, check if the one that you have is good enough. The `-v` command-line switch tells you which version you have:

```
$ perl -v
```

```
This is perl 5, version 34, subversion 0 (v5.34.0)
```

If you have a recent enough version, you don't have to do any more work. What you do next depends on how much work you'd like to do.

If you are stuck on a system without a compiler, you can try precompiled versions, including Strawberry Perl (Windows) or ActivePerl Community Edition (macOS, Windows, Linux, and others).

You can compile your own *perl*. We think that everyone should try compiling it themselves at least once in their lives. Part of being a programmer is understanding how actual computers work, and compiling source, managing libraries, and such are part of that. You can download the *perl* source from [CPAN](#). We tend to have them all installed so we can play with any version we like.

NOTE

You may have to install development tools to compile code. We can't tell you exactly what that is since systems have so many ways of managing that. Figure out how to install *gcc* (the GNU C compiler) and you'll probably get the rest of the tools you need. For macOS users, install the “[Command Line Tools for Xcode](#)” from Apple. [Cygwin](#) for Windows provides a Unix-like environment.

Once you unpack the source, you can configure the installation to tell it where you want to install it. You don't need special privileges to do this since you can install it into any directory you control:

```
$ ./Configure -des -Dprefix=/path/where/you/want/perl
```

We like to install several *perls*, so we create version-specific directories for each one:

```
$ ./Configure -des -Dprefix=/usr/local/perls/perl-5.34.0
```

From there, tell *make* to install it—this might take a bit:

```
$ make install
```

You might want to test the result before you install it. If the test step fails, *make* will not run the install step:

```
$ make test install
```

Once installed, we can use the new *perl* by specifying it in the shebang line:

```
#!/usr/local/perls/perl-5.34.0/bin/perl
```

You can also use the *perlbrew* application to install and manage several Perls. It's doing the same thing you did in the previous step, but automated. See <http://perlbrew.pl> for details.

Experimental Features

Let's get down to the actual features and how you use them. We aren't going to list every feature or fully explain the features we highlight. We want to show you how to use any new feature, not particular new features.

You can enable experimental features in several ways. The first is the `-E` command-line switch, introduced in v5.10. Like the `-e` switch, it specifies the program as an argument, but `-E` also enables all new features:

```
$ perl -E "say q(Hello World)"
```

Inside a program, you can enable new features with `use` and the version number in any format:

```
use v5.34;  
use 5.34.0;  
use 5.034;
```

Remember that since v5.12, specifying the version with `use` also implicitly turns on `strict`.

You can also specify the minimum version without loading new features; do it with `require`:

```
require v5.34;
```

The `feature` module allows you to load features when you want them. In the `use` example, Perl was doing this for you by implicitly calling it to load the tag associated with that version:

```
use feature qw(:5.10);
```

Instead of loading all the new features for a particular version, you can load them individually.

In [Chapter 4](#) we showed you `state` (a stable feature that showed up in v5.10) and `signatures` (an experimental feature introduced in v5.20):

```
use feature qw(state signatures);
```

If you want to turn off all new features, perhaps because you have an old script that doesn't work with the newer Perls, you can disable them:

```
no feature qw(:all);
```

Of course, you need a version of Perl that has the `feature` module for this to work. That probably means that you are running an old program on a new *perl*, or perhaps you're still getting used to the new features and don't want to accidentally use them.

NOTE

We don't cover the complexities of `no` in this book, but it's the opposite of `use`. You're actually *un*-importing something.

Turning Off Experimental Warnings

Having turned on some experimental features, you'll get some warnings when you use those features. *perl* doesn't emit the warning when you enable the features. This simple program enables `signatures` but has no warnings:

```
use v5.20;
use feature qw(signatures);
```

This program uses a subroutine signature:

```
use v5.20;
use feature qw(signatures);

sub division ( $m, $n ) {
    eval { $m / $n }
}
```

You get the warning even though you don't call the subroutine:

```
The signatures feature is experimental at features.pl line 4.
```

To turn off these warnings, prefix the feature name with `experimental::`, like this:

```
no warnings qw(experimental::signatures);
```

If you want to turn off all experimental warnings, leave off the name of the feature:

```
no warnings qw(experimental);
```

Starting with v5.18, the `experimental` pragma enables the feature and disables its warnings in one step. This is a bit tidier:

```
use experimental qw(current_sub);
```

Enable or Disable Features Lexically

If you are a bit skittish about experimental features, you can enable them lexically and give them the smallest (or largest) scope that makes you comfortable.

Here's a program where you've defined your own version of `say`. Perhaps you did that before v5.10 existed. You want to add some new code to use the built-in version of `say`. The `feature` pragma enables it only for the block where you declare it:

```

require v5.10;
sub say {
    print "Someone said \"@_\"\\n";
}

say( "Hello Fred!" );

{ # use the built-in say in here
use feature qw(say);
say "Hello Barney!";
}

say( "Hello Dino!" );

```

The output shows you using both versions in the same program:

```

Someone said "Hello Fred!"
Hello Barney!
Someone said "Hello Dino!"

```

This also means you have to enable the features per file since Perl treats a file as a scope as if it had virtual braces around it. However, you'll have to keep reading in *Intermediate Perl* to learn more about multifile programs.

Don't Rely on Experimental Features

Experimental features are bright and shiny, novel, and expectedly attractive. But they might disappear and we don't quite know what they are going to do in the next version.

For code that won't make it to the outside world (even if that world is outside your group but still in your company), experiment all that you want. Remember, however, that virtually everything leaks out even if you try to contain it. You might have to rip out the shiny bits when the Porters decide to remove those experimental features.

If you know your code is destined for the outside world, realize that experimental features require a recent version of Perl. As much as everyone might wish that everyone used the latest version of Perl, we know that's not the case. If your creation is exciting enough, people may be motivated to migrate. The rest will complain that they are limited by local policy. You can't win.

No matter which situation you are in, try the experimental features. Learn what they do, see how they work, and tell people what you've found. That's why they are there for you, and feedback helps the Porters fix or adjust their behavior.

Table D-1 provides a breakdown of major new features and the version of *perl* that you will need.

Table D-1. Perl's new features

Feature	Introduced in	Experimental	Stable in	Documented in	Covered in
array_base	v5.10		v5.10	perlvar	
bitwise	v5.22		5.28	perlop	Chapter 12
current_sub	v5.16		v5.20	perlsub	
declared_refs	v5.26	✓		perlref	
evalbytes	v5.16		v5.20	perlfunc	
fc	v5.16		v5.20	perlfunc	
isa	v5.32	✓		perlfunc	
lexical_subs	v5.18		5.26	perlsub	
postderef	v5.20		v5.24	perlref	
postderef_qq	v5.20		v5.24	perlref	
refaliasing	v5.22	✓		perlref	
regex_sets	v5.18	✓		perlrecharclass	
say	v5.10		v5.10	perlfunc	Chapter 5
signatures	v5.20	✓		perlsub	Chapter 4
state	v5.10		v5.10	perlfunc , perlsub	Chapter 4
switch	v5.10	✓		perlsyn	
try-catch	v5.34	✓		perlsyn	
unicode_eval	v5.16			perlfunc	
unicode_strin gs	v5.12			perlunicode	
vlb	v5.30	✓		perlre	

Index

Symbols

! (negation operator), [The unless Control Structure](#)

(pound sign), [What's Inside That Program?](#), [Adding Whitespace with /x](#)

#! (shebang) line, [What's Inside That Program?](#)

\$ (dollar sign), [A Simple Program](#), [Scalar Variables](#), [Interpolation of Scalar Variables into Strings](#)

\$_ special variable, [Fatal Errors with die](#), [File Test Operators](#), [Changing the Directory](#)

\$" special variable, [Output to Standard Output](#)

\$\$ special variable, [Using Backquotes to Capture Output](#)

\$' special variable, [The Automatic Match Variables](#)

\$= special variable, [Subroutine Signatures](#)

\$? special variable, [Processes as Filehandles](#)

\$@ special variable, [More Advanced Error Handling](#)

\$HOME shell variable, [The system Function](#)

\$_ special variable, [Perl's Favorite Default: \\$_](#), [Sequences](#), [Choosing a Character Interpretation](#)

\$` special variable, [The Automatic Match Variables](#)

\$| special variable, [Changing the Default Output Filehandle](#)

% (modulus operator), [Numeric Operators](#)

% (percent sign), [Formatted Output with printf](#), [Formatted Output with printf](#), [The Hash as a Whole](#)

& (ampersand), [Subroutines](#), [Omitting the Ampersand](#)-[Omitting the Ampersand](#)

& (bitwise-and operator), [Bitwise Operators](#)

&& (logical AND operator), [Logical Operators](#)

' (apostrophe), [Hash Element Interpolation](#)

' (single quote), [Single-Quoted String Literals](#)

() parentheses

capture groups, [Grouping in Patterns](#)-[Grouping in Patterns](#)

match variables and, [The Match Variables](#)-[The Automatic Match Variables](#)

noncapturing, [Noncapturing Parentheses](#), [The split Operator](#)

order of precedence, [Operator Precedence and Associativity](#), [Precedence](#)

print() function and, [Output to Standard Output](#)

prototypes and, [Prototypes](#)

* (star) metacharacter, [Quantifiers](#), [Precedence](#)

** (exponentiation operator), [Numeric Operators](#)

+ (plus) metacharacter, [Quantifiers](#), [Precedence](#)

++ (autoincrement operator), [Autoincrement and Autodecrement](#)-[The Value of Autoincrement](#)

- (hyphen), [Character Classes](#)

-- (autodecrement operator), [Autoincrement and Autodecrement](#)

. (dot), [The Wildcard](#)

.. (range operator), [List Literals](#)

... (yada yada operator), [The foreach Control Structure](#)

./ (dot-slash), [A Simple Program](#)

/ (forward slash), [Matches with m//](#)

// (defined-or operator), [The defined-or Operator](#)

:: (double colon), [Hash Element Interpolation](#)

;; (semicolon), [What's Inside That Program?](#), [In-Place Editing from the Command Line](#)

<<>> (double diamond operator), [The Double Diamond](#)

<> (diamond operator), [Input from the Diamond Operator-The Double Diamond](#), [The Invocation Arguments](#), [Updating Many Files](#)

= (binding operator), [The Binding Operator =~](#), [The Binding Operator](#), [Manipulating a Substring with substr](#)

=> (big arrow), [The Big Arrow](#), [Renaming Files](#)

? (question mark) metacharacter, [Quantifiers](#), [Precedence](#)

?: (conditional operator), [The Conditional Operator-The Conditional Operator](#)

@ (at sign), [List Assignment](#)

@_ special variable, [Arguments](#)

\ (backslash), [Single-Quoted String Literals](#), [Interpolation of Scalar Variables into Strings](#), [Hash Element Interpolation](#)

_ (underscore), [Integer Literals](#), [Choosing Good Variable Names](#), [The use strict Pragma](#)

` (backquote), [A Whirlwind Tour of Perl, Using Backquotes to Capture Output-Using Backquotes in a List Context](#)

{ } (curly braces)

as delimiters, [Matches with m//](#), [Combining Option Modifiers](#)

hashes and, [Hash Element Access](#)

if control structure and, [The if Control Structure](#)

repetition operators, [Quantifiers](#), [Precedence](#)

usage considerations, [Hash Element Interpolation](#)

variable names and, [Interpolation of Scalar Variables into Strings](#)

while control structure and, [The while Control Structure](#)

| (vertical bar of alternation), [Alternation-Alternation](#), [Precedence](#)

|| (logical OR operator), [Logical Operators](#)

A

\A anchor, [Anchors](#)

-A file test, [File Test Operators](#)

/a modifier, [Choosing a Character Interpretation](#)

ampersand (&), [Subroutines](#), [Omitting the Ampersand-Omitting the Ampersand](#)

anchors for patterns

about, [Anchors-Word Anchors](#)

beginning-of-line, [Beginning- and End-of-Line Anchors](#)

end-of-line, [Beginning- and End-of-Line Anchors](#)

order of precedence, [Precedence](#)

word anchors, [Word Anchors](#)

anonymous subroutines, [Anonymous Subroutines and Closures](#)

Apache web servers, [Embedding](#)

apostrophe ('), [Hash Element Interpolation](#)

append operator, [Compound Assignment Operators](#)

arguments in subroutines, [Arguments-Arguments](#)

ARGV filehandle, [Filehandles](#)

\$ARGV special variable, [Input from the Diamond Operator](#)

@ARGV special variable, [Input from the Diamond Operator](#), [Dealing with Command-Line Arguments](#)

ARGVOUT filehandle, [Filehandles](#)

arrays

about, [Lists and Arrays](#)

accessing elements of, [Accessing Elements of an Array](#)

additional functionality, [Lists and Arrays](#)

context of the expression, [Scalar and List Context-Forcing Scalar Context](#)

elements of, [Lists and Arrays](#)

empty list, [Using Scalar-Producing Expressions in List Context](#), [Notes on Lexical \(my\) Variables](#)

foreach control structure and, [The foreach Control Structure-The each Operator](#)

interpolating into strings, [Interpolating Arrays into Strings](#), [Output to Standard Output](#)

list assignment, [List Assignment-The splice Operator](#)

print() function and, [Output to Standard Output](#)

printf() function and, [Arrays and printf](#)

referencing entire, [List Assignment](#)

slicing elements from, [Array Slice-Array Slice](#)

special indices, [Special Array Indices](#)

subscripting, [Accessing Elements of an Array](#)

vec operator and, [Bits and Pieces](#)

array_base feature, [Don't Rely on Experimental Features](#)

assignment operators, [Compound Assignment Operators](#)

associativity of operators, [Operator Precedence and Associativity-Operator Precedence and Associativity](#)

at sign (@), [List Assignment](#)

atoms, [Precedence](#)

autodecrement operator (--), [Autoincrement and Autodecrement](#)

autodecrementing scalar variables, [Autoincrement and Autodecrement](#)

autodie pragma, [Automatically die-ing](#)

autoincrement operator (++), [Autoincrement and Autodecrement-The Value of Autoincrement](#)

autoincrementing scalar variables, [Autoincrement and Autodecrement-The Value of Autoincrement](#)

automatic match variables, [The Automatic Match Variables-The Automatic Match Variables](#)

autovivification feature, [Hash Element Access](#)

awk language, [What Is a Hash?](#)

B

\b (word-boundary) anchor, [Word Anchors](#), [Fancier Word Boundaries](#)

-b file test, [File Test Operators](#)

-B file test, [File Test Operators](#)

B::Lint module, [Debugging](#)

back references, [Grouping in Patterns-Grouping in Patterns](#)

backquote (``), [A Whirlwind Tour of Perl](#), [Using Backquotes to Capture Output-Using Backquotes in a List Context](#)

backslash (\), [Single-Quoted String Literals](#), [Interpolation of Scalar Variables into Strings](#), [Hash Element Interpolation](#)

backslash escapes, [Single-Quoted String Literals](#), [The Wildcard](#), [Case Shifting](#)

barewords, [Filehandles](#), [The Big Arrow](#), [Directory Handles](#)

BBEdit editor, [How Do I Make a Perl Program?](#)

beginning-of-line anchors, [Beginning- and End-of-Line Anchors](#)

big arrow (=>), [The Big Arrow](#), [Renaming Files](#)

binary literals, [Nondecimal Integer Literals](#)

binding operator (=), [The Binding Operator =~](#), [The Binding Operator](#), [Manipulating a Substring with substr](#)

binmode() function, [Binmoding Filehandles](#), [Reading from STDIN or Writing to STDOUT or STDERR](#)

bitstrings, [Using Bitstrings-Using Bitstrings](#)

bitwise feature, [Using Bitstrings](#), [Don't Rely on Experimental Features](#)

bitwise operators, [Bitwise Operators-Using Bitstrings](#)

bitwise-and (&) operator, [Bitwise Operators](#)

Boolean values, [Boolean Values](#), [The keys and values Functions](#), [Substitutions with s///](#)

bug reporting in Perl, [What If I Find a Bug in Perl?](#)

built-in variables, [Built-in Variables](#)

built-in warnings, [Perl's Built-in Warnings-Interpreting Nondecimal Numerals](#)

bytecodes, [How Do I Compile My Perl Program?](#)

C

-c file test, [File Test Operators](#)

-C file test, [File Test Operators](#)

canonically equivalent characters, [Fancier Characters](#)

@{^CAPTURE} array variable, [m// in List Context](#)

capture groups

 grouping in patterns, [Grouping in Patterns-Grouping in Patterns](#)

 match variables, [The Match Variables-The Automatic Match Variables](#)

Capture::Tiny module, [Using Backquotes to Capture Output](#)

carriage-return/linefeed (CR-LF), [Opening a Filehandle](#)

case folding, Unicode bug, [Choosing a Character Interpretation](#)

case shifting, [Case Shifting-Case Shifting](#)

cat Unix command, [Output to Standard Output, Filehandles](#)

catch block, [More Advanced Error Handling](#)

cd Unix command, [Changing the Directory](#)

character classes, [Character Classes-Negating the Shortcuts](#)

chardnames pragma, [Fancier Characters by Name](#)

chdir() function, [Changing the Directory](#)

chmod Unix command, [A Simple Program](#)

chmod() function, [Removing Files, Modifying Permissions](#)

chomp() function, [The chomp Operator](#), [<STDIN> in List Context](#), [Answers to Chapter 2 Exercises](#)

chown() function, [Changing Ownership](#)

chr() function, [Creating Characters by Code Point](#), [Choosing a Character Interpretation](#)

CLDR::Number module, [Using sprintf with “Money Numbers”](#)

close() function, [Closing a Filehandle](#)

closures, [Anonymous Subroutines and Closures](#)

cmp comparison operator, [Advanced Sorting](#)

code points

- creating characters by, [Creating Characters by Code Point](#)
- mapping characters to, [Unicode](#)
- Unicode considerations, [Fancy Characters](#)

comma-separated values (CSV) files, [The split Operator](#)
comments, [What's Inside That Program?](#), [Adding Whitespace with /x](#)
comparison operators, [Comparison Operators](#), [Advanced Sorting](#)
compatibility equivalent characters, [Fancier Characters](#)
compiling Perl programs, [How Do I Compile My Perl Program?](#)
composed characters, [Fancy Characters](#)
compound assignment operators, [Compound Assignment Operators](#)
Comprehensive Perl Archive Network (see CPAN)
concatenation operator, [String Operators](#), [Compound Assignment Operators](#)
conditional operator (?:), [The Conditional Operator-The Conditional Operator](#)
Config module, [The Environment Variables](#)
context of the expression, [Scalar and List Context-Forcing Scalar Context](#)
Control-Z bug, [<STDIN> in List Context](#)
converting between numbers and strings, [Automatic Conversion Between Numbers and Strings](#)
CPAN (Comprehensive Perl Archive Network)
 about, [What Is CPAN?](#), [Perl Modules](#)
 module list, [And More...](#)
 Text::CSV_XS module, [The split Operator](#)
cpan command, [Finding Modules](#)
CPAN.pm module, [Installing Modules](#)
cpanm tool, [Installing Modules](#)

CR-LF (carriage-return/linefeed), [Opening a Filehandle](#)

CSV (comma-separated values) files, [The split Operator](#)

curly braces ({})

as delimiters, [Matches with m//](#), [Combining Option Modifiers](#)

hashes and, [Hash Element Access](#)

if control structure and, [The if Control Structure](#)

repetition operators, [Quantifiers](#), [Precedence](#)

usage considerations, [Hash Element Interpolation](#)

variable names and, [Interpolation of Scalar Variables into Strings](#)

while control structure and, [The while Control Structure](#)

current working directory, [The Current Working Directory-The Current Working Directory](#)

current_sub feature, [Don't Rely on Experimental Features](#)

Cwd module, [The Current Working Directory](#)

D

\d (digit) shortcut, [Character Class Shortcuts](#)

-d file test, [File Test Operators](#)

%d format, [Formatted Output with printf](#)

DATA filehandle, [Filehandles](#)

data-flow analysis, [Security](#)

Database Driver (DBD), [Databases and DBI](#)

databases

additional information, [Dealing with Databases](#)

Perl support, [Databases](#)

date and time modules, [Dates and Times](#)

date Unix command, [The system Function](#), [Using Backquotes to Capture Output](#)

DateTime module, [Dates and Times](#)

DBD (Database Driver), [Databases and DBI](#)

DBI module, [Databases and DBI](#), [Databases](#), [Dealing with Databases](#)

debugging

about, [Debugging](#)

print() function and, [Return Values](#)

declared_refs feature, [Don't Rely on Experimental Features](#)

decoding, [Unicode](#)

defined() function, [The defined Function](#), [Changing Ownership](#)

defined-or operator (//), [The defined-or Operator](#)

delete() function, [The delete Function](#)

delimiters for pattern matching, [Matches with m//](#), [Combining Option Modifiers](#), [Different Delimiters](#)

diagnostics pragma, [Perl's Built-in Warnings](#)

diamond operator (<>), [Input from the Diamond Operator-The Double Diamond](#), [The Invocation Arguments](#), [Updating Many Files](#)

die() function, [Fatal Errors with die-Automatically die-ing](#)

Digest::SHA module, [Finding Modules](#)

Digit property, [Unicode Properties](#)

dir command (Windows), [The system Function](#)

directory handles, [Directory Handles-Directory Handles](#)

directory operations, [Directory Operations-Changing Timestamps](#)

 alternate syntax for globbing, [An Alternate Syntax for Globbing](#)

 changing directories, [Changing the Directory-Changing the Directory](#)

 changing file ownership, [Changing Ownership](#)

 changing file timestamps, [Changing Timestamps](#)

 current working directory, [The Current Working Directory-The Current Working Directory](#)

 directory handles, [Directory Handles-Directory Handles](#)

 globbing, [Globbing-An Alternate Syntax for Globbing](#)

 links and files, [Links and Files-Links and Files](#)

 making directories, [Making and Removing Directories-Making and Removing Directories](#)

 manipulating directories, [Manipulating Files and Directories](#)

 modifying permissions, [Modifying Permissions](#)

 removing directories, [Making and Removing Directories-Making and Removing Directories](#)

 removing files, [Removing Files-Removing Files](#)

 renaming files, [Renaming Files-Renaming Files](#)

 specifying installation location, [Installing Modules, Using Your Own Directories-Using Your Own Directories](#)

documentation

embedded, [Embedded Documentation](#)

perldebug, [Debugging](#)

perldelta, [Experimental Features](#)

perldiag, [What's Inside That Program?](#)

perldsc, [List Assignment](#), [Complex Data Structures](#)

perlfaq, [How Do I Make a Perl Program?](#), [How Do I Make a Perl Program?](#), [Further Documentation](#)

perlform, [Formats](#)

perlfunc, [Formatted Output with printf](#), [The Naked Block Control Structure](#), [Mathematics](#), [System V IPC](#)

perlhist, [A Short History of Perl Development](#)

perlipc, [Getting Down and Dirty with fork](#), [System V IPC](#)

perllool, [Complex Data Structures](#)

perlobj, [Object-Oriented Programming](#)

perloutut, [Object-Oriented Programming](#)

perlprep, [Operator Precedence and Associativity](#)

perlperntut, [More Ways to Open Filehandles](#)

perlppod, [Embedded Documentation](#)

perlpolicy, [Perl 5.10 and Beyond](#)

perlport, [The stat and lstat Functions](#)

perlre, [Choosing a Character Interpretation](#), [Regular Expressions](#)

perlref, [References](#)

perlrun, [Command-Line Options](#), [Reading from STDIN or Writing to STDOUT or STDERR](#)

perlsec, [Avoiding the Shell](#), [Security](#)

perlstyle, [What's Inside That Program?](#), [Choosing Good Variable Names](#)

perlsub, [Subroutine Signatures](#)

perlty, [Tied Variables](#)

perltoc, [Further Documentation](#)

perlunicode, [Choosing a Character Interpretation](#)

perluniprops, [Unicode Properties](#)

perlvar, [Choosing Good Variable Names](#)

dollar sign (\$), [A Simple Program](#), [Scalar Variables](#), [Interpolation of Scalar Variables into Strings](#)

dot (.), [The Wildcard](#)

double colon (::), [Hash Element Interpolation](#)

double diamond operator (<<>>), [The Double Diamond](#)

double-quote interpolation, [Double-Quoted String Literals](#), [Interpolation of Scalar Variables into Strings](#)

double-quoted string literals, [Double-Quoted String Literals](#), [Sequences](#)

dualvar, [Using Bitstrings](#)

E

\E escape, [Case Shifting](#), [Metaquoting](#)

-e file test, [File Test Operators](#)

each() function, [The each Operator](#), [The each Function-The each Function](#)

echo Unix command, [Globbing](#)

else clause

if control structure, [The if Control Structure](#), [The else Clause with unless](#), [The elsif Clause](#)

unless control structure, [The else Clause with unless](#)

elsif clause (if control structure), [The elsif Clause](#)

emacs editor, [How Do I Make a Perl Program?](#)

email addresses in strings, [Interpolating Arrays into Strings](#)

embedded documentation, [Embedded Documentation](#)

embedding Perl, [Embedding](#)

empty list, [Using Scalar-Producing Expressions in List Context](#), [Notes on Lexical \(my\) Variables](#)

empty parameter lists, [Empty Parameter Lists](#)

empty string, [Strings](#), [Interpolation of Scalar Variables into Strings](#)

Encode::Guess module, [Reading from and Writing to Files](#)

encoding

about, [Unicode](#)

open() function specifying, [Opening a Filehandle](#)

UTF-16, [Opening a Filehandle](#), [UTF-8 and Friends](#)

UTF-8, [Strings](#), [Opening a Filehandle](#), [UTF-8 and Friends](#), [Using Unicode in Your Source](#)

`__END__` token, [The last Operator](#), [Labeled Blocks](#)

end-of-file, [<STDIN> in List Context](#), [Bad Filehandles](#)

end-of-line anchors, [Beginning- and End-of-Line Anchors](#)

%ENV hash, [The %ENV Hash](#), [The defined-or Operator](#)

\$ENV special variable, [Changing the Directory](#), [Avoiding the Shell](#)

environment variables

- encoding support, [Getting Everyone to Agree](#)
- %ENV hash, [The %ENV Hash](#), [The defined-or Operator](#)
- setting, [Using Your Own Directories](#), [Changing the Directory](#), [The Environment Variables-The Environment Variables](#)
- VERBOSE, [The defined-or Operator](#)

eq string comparison operator, [Comparison Operators](#)

error handling, [Trapping Errors-Using eval](#)

eval() function, [Using eval-Using eval](#)

evalbytes feature, [Don't Rely on Experimental Features](#)

exec() function, [The exec Function](#)

exists() function, [The exists Function](#)

exit() function, [Using eval](#)

experimental features, [Experimental Features-Don't Rely on Experimental Features](#)

exponential notation, [Floating-Point Literals](#)

exponentiation operator (**), [Numeric Operators](#)

ExtUtils::MakeMaker module, [Installing Modules](#), [Using Your Own Directories](#)

F

\F escape, [Case Shifting](#)

-f file test, [File Test Operators](#)

%f format, [Formatted Output with printf](#)

fat arrow (=>), [The Big Arrow](#), [Renaming Files](#)

fc() function, [Case Shifting](#), [Don't Rely on Experimental Features](#)

feature module, [Experimental Features](#), [Experimental Features](#)

feature pragma, [Enable or Disable Features Lexically](#)

file management

- alternate syntax for globbing, [An Alternate Syntax for Globbing](#)

- changing file ownership, [Changing Ownership](#)

- changing file timestamps, [Changing Timestamps](#)

- globbing, [Globbing-An Alternate Syntax for Globbing](#)

- in-place editing of files, [Updating Many Files-Updating Many Files](#)

- links and files, [Links and Files-Links and Files](#)

- manipulating file specifications, [The File::Spec Module-The File::Spec Module](#)

- manipulating files, [Manipulating Files and Directories](#)

- modifying permissions, [Modifying Permissions](#)

- reading from files, [Reading from and Writing to Files](#)

- removing files, [Removing Files-Removing Files](#)

- renaming files, [Renaming Files-Renaming Files](#)

updating multiple files, [Updating Many Files-In-Place Editing from the Command Line](#)

writing to files, [Reading from and Writing to Files](#)

file tests, [File Tests-Using Bitstrings](#)

bitwise operators, [Bitwise Operators-Using Bitstrings](#)

localtime() function, [The localtime Function](#)

lstat() function, [The stat and lstat Functions-The stat and lstat Functions](#)

multiple attributes for files, [Testing Several Attributes of the Same File](#)

operators supported, [File Test Operators-Stacked File Test Operators](#)

stacked operators, [Stacked File Test Operators-Stacked File Test Operators](#)

stat() function, [The stat and lstat Functions-The stat and lstat Functions](#)

File::Basename module, [The File::Basename Module-Using Only Some Functions from a Module](#)

File::chmod module, [Modifying Permissions](#)

File::Glob module, [Globbing](#)

File::HomeDir module, [Changing the Directory](#)

File::Path module, [Making and Removing Directories](#)

File::Spec module, [The File::Spec Module-The File::Spec Module, The Current Working Directory](#)

File::Spec::Functions module, [Directory Handles](#)

File::stat module, [The stat and lstat Functions](#)

File::Temp module, [Making and Removing Directories](#), [Sending and Receiving Signals](#)

filehandles, [Filehandles-Closing a Filehandle](#)

about, [Filehandles-Closing a Filehandle](#)

bad, [Bad Filehandles](#)

binmoding, [Binmoding Filehandles](#), [Reading from STDIN or Writing to STDOUT or STDERR](#)

changing default output, [Changing the Default Output Filehandle](#)

closing, [Closing a Filehandle](#)

in scalar variables, [Filehandles in a Scalar](#)-[Filehandles in a Scalar](#)

indirect filehandle read, [An Alternate Syntax for Globbing](#)

opening, [Opening a Filehandle](#)-[Closing a Filehandle](#), [More Ways to Open Filehandles](#)

processes as, [Processes as Filehandles](#)-[Processes as Filehandles](#)

reopening, [Reopening a Standard Filehandle](#)

Unicode considerations, [Reading from STDIN or Writing to STDOUT or STDERR](#)

usage considerations, [Using Filehandles](#)

finally block, [More Advanced Error Handling](#)

find Unix command, [Processes as Filehandles](#), [Converting find Command Lines to Perl](#)

find2perl command, [Converting find Command Lines to Perl](#)

FindBin module, [Using Your Own Directories](#)

floating-point literals, [Floating-Point Literals](#)

for control structure, [The for Control Structure-The Secret Connection Between foreach and for](#)

foreach control structure

about, [The foreach Control Structure-The each Operator](#)

example of, [Answers to Chapter 4 Exercises](#)

for control structure and, [The Secret Connection Between foreach and for](#)

grep operator and, [Picking Items from a List with grep](#)

lexical variables in, [Notes on Lexical \(my\) Variables](#)

loop controls, [The last Operator](#)

map operator and, [Transforming Items from a List with map](#)

statement modifiers and, [Statement Modifiers](#)

fork() function, [Getting Down and Dirty with fork](#)

formats

about, [Formats](#)

formatted output, [Formatted Output with printf-Arrays and printf](#)

formatting data with sprintf() function, [Formatting Data with sprintf-Using sprintf with “Money Numbers”](#)

forward slash (/), [Matches with m//](#)

G

\G anchor, [Precedence](#)

-g file test, [File Test Operators](#)

%g format, [Formatted Output with printf](#)

/g modifier, [Global Replacements with /g, m// in List Context](#)

Garcia-Suarez, Rafael, [Perl 5.10 and Beyond](#)

gcc compiler, [Installing a Recent Perl](#)

ge string comparison operator, [Comparison Operators](#), [Advanced Sorting](#)

Getopt::Long module, [The Invocation Arguments](#), [Command-Line Options in Your Programs](#)

Getopt::Std module, [The Invocation Arguments](#), [Command-Line Options in Your Programs](#)

getpwnam() function, [Changing Ownership](#)

glob() function, [Globbing](#), [Removing Files](#)

global variables, [Defining a Subroutine](#)

globbing, [Globbing-An Alternate Syntax for Globbing](#)

glyph (grapheme), [Fancy Characters](#)

gmtime() function, [The localtime Function](#)

grapheme (glyph), [Fancy Characters](#)

graphical user interfaces (GUIs), [Graphical User Interfaces \(GUIs\)](#)

greedy quantifiers, [Quantifiers](#)

grep list-processing operator, [Picking Items from a List with grep](#), [Lists and Arrays](#)

grep Unix command, [Filehandles](#), [Picking Items from a List with grep](#)

gt string comparison operator, [Comparison Operators](#)

GUIs (graphical user interfaces), [Graphical User Interfaces \(GUIs\)](#)

H

\h (horizontal whitespace) shortcut, [Character Class Shortcuts](#)

hard links, [Links and Files](#)

hash keys, [What Is a Hash?-What Is a Hash?](#), [Sorting by Multiple Keys](#)

hashes

- about, [What Is a Hash?-What Is a Hash?](#)

- accessing elements of, [Hash Element Access-The Big Arrow](#)

- assigning to one another, [Hash Assignment](#)

- converting into lists, [The Hash as a Whole](#)

- functions, [Hash Functions-The each Function](#)

- interpolating elements into strings, [Hash Element Interpolation](#)

- referencing entire, [Hash Functions-The each Function](#)

- slicing elements from, [Hash Slice-Hash Slice](#)

- sorting by multiple keys, [Sorting by Multiple Keys](#)

- sorting by value, [Sorting a Hash by Value](#)

- typical applications, [Why Use a Hash?](#), [Typical Use of a Hash-Hash Element Interpolation](#)

- unwinding, [The Hash as a Whole](#)

Hello, world program, [A Simple Program-How Do I Compile My Perl Program?](#)

hex() function, [Interpreting Nondecimal Numerals](#)

hexadecimal literals, [Nondecimal Integer Literals](#)

hyphen (-), [Character Classes](#)

I

/i modifier, [Case-Insensitive Matching with /i](#), [Substitution Modifiers](#)

I/O (see input/output)

if control structure

about, [The if Control Structure-Boolean Values](#)

conditional operator and, [The Conditional Operator](#)

else clause, [The if Control Structure](#), [The else Clause with unless](#), [The elsif Clause](#)

elsif clause, [The elsif Clause](#)

lexical variables in, [Notes on Lexical \(my\) Variables](#)

pattern matching and, [The Persistence of Captures](#)

statement modifiers and, [Statement Modifiers-Statement Modifiers](#)

in-place editing of files, [Updating Many Files-Updating Many Files](#)

indents in Perl programs, [What's Inside That Program?](#)

index() function, [Finding a Substring with index](#)-[Finding a Substring with index](#)

indirect filehandle read, [An Alternate Syntax for Globbing](#)

infinite loops, [The for Control Structure](#)

Inline modules, [Using Other Languages Inside Perl](#)

inode, [Links and Files](#)-[Links and Files](#)

input/output (I/O), [Input and Output](#)-[Exercises](#)

backquotes to capture output, [Using Backquotes to Capture Output](#)-[Using Backquotes in a List Context](#)

fatal errors with die() function, [Fatal Errors with die-Automatically die-ing](#)

filehandles and, [Filehandles-Filehandles, Using Filehandles-Reopening a Standard Filehandle, Filehandles in a Scalar-Filehandles in a Scalar](#)

formatted output with printf() function, [Formatted Output with printf-Arrays and printf](#)

input from diamond operator, [Input from the Diamond Operator-The Double Diamond](#)

input from standard input, [Input from Standard Input-Input from Standard Input](#)

invocation arguments, [The Invocation Arguments](#)

output to standard output, [Output to Standard Output-Output to Standard Output](#)

output with print() function, [Output with print](#)

output with say() function, [Output with say](#)

installing

modules, [Installing Modules-Using Your Own Directories](#)

Perl, [Installing a Recent Perl-Installing a Recent Perl](#)

integer literals, [Integer Literals](#)

interprocess communication, [System V IPC](#)

invocation arguments, [Input from the Diamond Operator, The Invocation Arguments](#)

IO module, [Reading from STDIN or Writing to STDOUT or STDERR](#)

IPC::Open3 module, [Using Backquotes to Capture Output](#)

IPC::System::Simple module, [Using Backquotes to Capture Output, External Processes with IPC::System::Simple](#)

isa feature, [Don't Rely on Experimental Features](#)

isatty() function, [File Test Operators](#)

J

join() function, [The join Function](#), [The Environment Variables](#)

K

-k file test, [File Test Operators](#)

key-value slices, [Key-Value Slices](#)

keys() function, [The keys and values Functions](#)

kill Unix command, [Sending and Receiving Signals](#)

Komodo Edit editor, [How Do I Make a Perl Program?](#)

L

\l escape, [Case Shifting](#)

\L escape, [Case Shifting](#)

-l file test, [File Test Operators](#)

labeled blocks, [Labeled Blocks](#)

last() function, [The last Operator](#)

lc() function, [Case Shifting](#)

lcfirst() function, [Case Shifting](#)

LC_* environment variables, [Getting Everyone to Agree](#)

le string comparison operator, [Comparison Operators](#)

leading zero indicator, [Nondecimal Integer Literals](#)

length() function, [Exercises](#)

lexical variables, [Private Variables in Subroutines](#), [Notes on Lexical \(my\) Variables](#), [Persistent](#), [Private Variables-Persistent](#), [Private Variables](#)

lexical_subs feature, [Don't Rely on Experimental Features](#)

lib pragma, [Using Your Own Directories](#)

ligature, [Fancier Characters](#)

line-input operator

- diamond operator, [Input from the Diamond Operator-The Double Diamond](#), [The Invocation Arguments](#)

- <STDIN>, [Getting User Input](#), [<STDIN> in List Context](#), [Input from Standard Input-Input from Standard Input](#)

link count, [Links and Files](#)

list context

- about, [Scalar and List Context](#)

- backquotes in, [Using Backquotes in a List Context-Using Backquotes in a List Context](#)

- m// in, [m// in List Context](#)

- reverse() function and, [Using List-Producing Expressions in Scalar Context](#), [Answers to Chapter 5 Exercises](#)

- scalar-producing expressions in, [Using Scalar-Producing Expressions in List Context](#)

<STDIN> operator in, <STDIN> in List Context, Input from Standard Input

list literals, List Literals-The qw Shortcut

List::MoreUtils module, Fancier List Utilities

List::Util module, Slices, Fancier List Utilities

lists

about, Lists and Arrays

additional functionality, Lists and Arrays

advanced sorting, Advanced Sorting-Sorting by Multiple Keys

assigning values to variables, List Assignment-The splice Operator

context of the expression, Scalar and List Context

converting hashes into, The Hash as a Whole

elements of, Lists and Arrays

empty, Using Scalar-Producing Expressions in List Context, Notes on Lexical (my) Variables

fancier handling, Fancier List Utilities-Fancier List Utilities

foreach control structure and, The foreach Control Structure-The each Operator

picking items with grep operator, Picking Items from a List with grep

qw() function and, The qw Shortcut

slicing elements from, Slices-Slices

transforming items with map operator, Transforming Items from a List with map

literals

dollar sign as, [Interpolation of Scalar Variables into Strings](#)

floating-point, [Floating-Point Literals](#)

integer, [Integer Literals](#)

list, [List Literals-The qw Shortcut](#)

string, [Single-Quoted String Literals-Double-Quoted String Literals, Sequences](#)

localtime() function, [Updating Many Files, The localtime Function](#)

logical AND operator (&&), [Logical Operators](#)

logical comparison operators, [Comparison Operators](#)

logical operators, [Logical Operators-Control Structures Using Partial-Evaluation Operators](#)

logical OR operator (||), [Logical Operators](#)

loop controls, [Loop Controls-Labeled Blocks](#)

about, [Loop Controls](#)

intentional infinite loops, [The for Control Structure](#)

labeled blocks, [Labeled Blocks](#)

last() function, [The last Operator](#)

next() function, [The next Operator](#)

redo() function, [The redo Operator](#)

lpr Unix command, [Filehandles](#)

ls Unix command, [The system Function](#)

lstat() function, [The stat and lstat Functions-The stat and lstat Functions](#)

lt string comparison operator, [Comparison Operators](#)

lvalue, [Substitutions with s///](#)

LWP module, [Sockets](#)

M

-M file test, [File Test Operators](#)

/m modifier, [Beginning- and End-of-Line Anchors](#), [Substitution Modifiers](#), [Matching Multiple-Line Text](#)

m// (pattern match operator), [Matches with m//](#)-[Matches with m//](#), [m// in List Context](#)

make utility, [Fatal Errors with die](#), [The Environment Variables](#)

map list-processing operator, [Transforming Items from a List with map](#), [Lists and Arrays](#)

mark characters, [Fancy Characters](#)

match operator, [Sequences](#)

match variables, [The Match Variables](#)-[The Automatic Match Variables](#)

about, [The Match Variables](#)

automatic, [The Automatic Match Variables](#)-[The Automatic Match Variables](#)

captures in alternations, [Captures in Alternations](#)-[Captures in Alternations](#)

named captures, [Named Captures](#)-[Named Captures](#)

noncapturing parentheses, [Noncapturing Parentheses](#)

persistence of captures, [The Persistence of Captures](#)

matching with regular expressions

binding operator, [The Binding Operator =~](#)

match modifiers, [Match Modifiers-Other Options](#)

match variables, [The Match Variables-The Automatic Match Variables](#)

pattern match operator, [Matches with m//-Matches with m//](#)

pattern test program, [A Pattern Test Program](#)

precedence, [Precedence-And There's More](#)

Math::BigFloat module, [Mathematics](#)

Math::BigInt module, [Mathematics](#)

Math::Complex module, [Mathematics](#)

metacharacters, [The Wildcard](#), [Metaquoting](#)

metaquoting, [Metaquoting](#)

mkdir() function, [Making and Removing Directories](#)

Module::Build module, [Installing Modules](#), [Using Your Own Directories](#)

Module::CoreList module, [Exercises](#)

modules, [Perl Modules-Dates and Times](#)

(see also specific modules)

finding, [Finding Modules](#)

installing, [Installing Modules-Using Your Own Directories](#)

using only some functions from, [Using Only Some Functions from a Module](#)

using simple, [Using Simple Modules-Dates and Times](#)

modulus operator (%), [Numeric Operators](#)

mod_perl module (Apache server), [Embedding](#)

Mojo::UserAgent module, [Sockets](#)

money numbers, [Using sprintf with “Money Numbers”](#)

Moose meta-object system, [Object-Oriented Programming](#)

mounted volumes, [Links and Files](#)

multiple files, updating, [Updating Many Files-In-Place Editing from the Command Line](#)

multiple-line text, matching, [Matching Multiple-Line Text](#)

mv Unix command, [Renaming Files](#)

my() function, [Private Variables in Subroutines](#), [Notes on Lexical \(my\) Variables](#)

N

/n (noncapturing parentheses) flag, [Noncapturing Parentheses](#)

naked block control structure, [The Naked Block Control Structure](#), [The last Operator](#)

named captures, [Named Captures](#)-[Named Captures](#)

ne string comparison operator, [Comparison Operators](#)

negation operator (!), [The unless Control Structure](#)

negative numbers, [Numeric Operators](#)

Net:: namespace, [Sockets](#)

networking considerations, [Networking and IPC](#)

newline character, [What's Inside That Program?](#), [Single-Quoted String Literals](#), [The Wildcard](#), [Using Simple Modules](#)

next() function, [The next Operator](#)

NFD subroutine, [Fancier Characters](#)

NFKD subroutine, [Fancier Characters](#)

noncapturing parentheses, [Noncapturing Parentheses](#), [The split Operator](#)

nondecimal integer literals, [Nondecimal Integer Literals](#)

nondecimal numerals, interpreting, [Interpreting Nondecimal Numerals](#)

nongreedy quantifiers, [Nongreedy Quantifiers](#)

nonmark characters, [Fancy Characters](#)

nonpaired delimiters, [Matches with m//](#)

nonscalar return values, [Nonscalar Return Values](#)

not operator, [Control Structures Using Partial-Evaluation Operators](#)

Number::Format module, [Using sprintf with “Money Numbers”](#)

numbers

- converting to strings, [Automatic Conversion Between Numbers and Strings](#)

- internal formatting, [All Numbers Have the Same Format Internally](#)

- money, [Using sprintf with “Money Numbers”](#)-[Using sprintf with “Money Numbers”](#)

- negative, [Numeric Operators](#)

- nondecimal, [Interpreting Nondecimal Numerals](#)

- numeric operators and, [Numeric Operators](#)

radix of, [Interpreting Nondecimal Numerals](#)

numeric operators, [Numeric Operators](#), [Comparison Operators](#)

O

-o file test, [File Test Operators](#)

-O file test, [File Test Operators](#)

%o format, [Formatted Output with printf](#)

object-oriented programming (OOP), [Object-Oriented Programming](#)

oct() function, [Interpreting Nondecimal Numerals](#)

octal literals, [Nondecimal Integer Literals](#)

octets, Unicode and, [Unicode](#)

OOP (object-oriented programming), [Object-Oriented Programming](#)

opaque binary, [What Is Perl Not Good For?](#)

open pragma, [Reading from STDIN or Writing to STDOUT or STDERR](#)

open() function, [Opening a Filehandle-Closing a Filehandle](#), [Processes as Filehandles](#), [More Ways to Open Filehandles](#)

opendir() function, [Directory Handles](#)

operators

about, [Numeric Operators](#)

append, [Compound Assignment Operators](#)

assignment, [Compound Assignment Operators](#)

associativity of, [Operator Precedence and Associativity-Operator Precedence and Associativity](#)

autodecrement, [Autoincrement and Autodecrement](#)

autoincrement, [Autoincrement and Autodecrement-The Value of Autoincrement](#)

binding, [The Binding Operator =~](#), [The Binding Operator](#), [Manipulating a Substring with substr](#)

bitwise, [Bitwise Operators-Using Bitstrings](#)

comparison, [Comparison Operators](#), [Advanced Sorting](#)

compound assignment, [Compound Assignment Operators](#)

concatenation, [Automatic Conversion Between Numbers and Strings](#), [Compound Assignment Operators](#)

conditional, [The Conditional Operator-The Conditional Operator](#)

file test, [File Test Operators-Stacked File Test Operators](#)

logical, [Logical Operators-Control Structures Using Partial-Evaluation Operators](#)

loop controls, [Loop Controls-Labeled Blocks](#)

negation, [The unless Control Structure](#)

numeric, [Numeric Operators](#), [Comparison Operators](#)

overloading, [Operator Overloading](#)

partial-evaluation, [Control Structures Using Partial-Evaluation Operators-Control Structures Using Partial-Evaluation Operators](#)

pattern match, [Matches with m/-Matches with m//](#), [m// in List Context](#)

precedence of, [Operator Precedence and Associativity-Operator Precedence and Associativity](#)

range, [List Literals](#)

repeat, [Quantifiers](#), [Precedence](#)

string, [String Operators](#), [Compound Assignment Operators](#)

string repetition, [String Operators](#)

vec, [Bits and Pieces](#)

word, [Control Structures Using Partial-Evaluation Operators](#)

ord() function, [Creating Characters by Code Point](#)

output (see input/output)

overload module, [Operator Overloading](#)

P

-p file test, [File Test Operators](#)

/p modifier, [The Automatic Match Variables](#)

packages, [Packages](#)

parameter lists, [Variable-Length Parameter Lists-Empty Parameter Lists](#)

parentheses ()

capture groups, [Grouping in Patterns-Grouping in Patterns](#)

match variables and, [The Match Variables-The Automatic Match Variables](#)

noncapturing, [Noncapturing Parentheses](#), [The split Operator](#)

order of precedence, [Operator Precedence and Associativity](#), [Precedence](#)

print() function and, [Output to Standard Output](#)

prototypes and, [Prototypes](#)

partial-evaluation operators, [Control Structures Using Partial-Evaluation Operators](#)-[Control Structures Using Partial-Evaluation Operators](#)

PATH environment variable, [The system Function](#)

Path::Class module, [Path::Class](#), [Directory Handles](#)

pattern match operator (m//), [Matches with m//](#)-[Matches with m//](#), [m// in List Context](#)

pattern matching (see [matching with regular expressions](#))

PDL module, [Mathematics](#)

percent sign (%), [Formatted Output with printf](#), [Formatted Output with printf](#), [The Hash as a Whole](#)

Perl

availability of, [How Can I Get Perl?](#)

background information, [What Does “Perl” Stand For?](#)-[What Is Perl Not Good For?](#)

built-in warnings, [Perl’s Built-in Warnings](#)-[Interpreting Nondecimal Numerals](#)

compiling programs, [How Do I Compile My Perl Program?](#)

development history, [A Short History of Perl Development](#)-[Perl 5.10 and Beyond](#)

embedding, [Embedding](#)

experimental features, [Experimental Features](#)-[Don’t Rely on Experimental Features](#)

extending functionality, [Extending Perl’s Functionality](#)

installing, [Installing a Recent Perl](#)-[Installing a Recent Perl](#)

programming considerations, [What's Inside That Program?-How Do I Compile My Perl Program?](#)

reference sources, [Is This the Right Book for You?](#), [Is There Any Kind of Support?](#)

reporting bugs, [What If I Find a Bug in Perl?](#)

sample program, [A Whirlwind Tour of Perl-A Whirlwind Tour of Perl](#)

support provided, [Is There Any Kind of Support?](#)

Unicode considerations, [Strings](#), [Dealing with Unicode in Perl-Dealing with Databases](#)

writing programs, [How Do I Make a Perl Program?-How Do I Compile My Perl Program?](#)

Perl identifier, [Interpreting Nondecimal Numerals](#), [Subroutines](#)

perl interpreter

- C switch, [Reading from STDIN or Writing to STDOUT or STDERR](#)

- e switch, [Answers to Chapter 1 Exercises](#)

- E switch, [Experimental Features](#)

- M option, [Perl's Built-in Warnings](#)

- p option, [In-Place Editing from the Command Line](#)

- w option, [Perl's Built-in Warnings](#), [Bad Filehandles](#), [Using eval](#)

compiling Perl programs, [How Do I Compile My Perl Program?](#)

installing, [Installing a Recent Perl-Installing a Recent Perl](#)

specifying command, [A Simple Program](#)

Perl Mongers, [Is There Any Kind of Support?](#)

Perl Power Tools project, [Output to Standard Output](#)

PERL5SHELL environment variable, [The system Function](#)

perlbrew application, [Installing a Recent Perl](#)

perlbug utility, [What If I Find a Bug in Perl?](#)

perldebug, [Debugging](#)

perldelta, [Experimental Features](#)

perldiag, [What's Inside That Program?](#)

perldoc command

- about, [Further Documentation](#)

- backquotes in, [A Whirlwind Tour of Perl, Using Backquotes to Capture Output](#)

- file test operators and, [File Test Operators](#)

- finding modules, [Finding Modules](#)

perldsc, [List Assignment, Complex Data Structures](#)

perlfaq, [How Do I Make a Perl Program?](#), [How Do I Make a Perl Program?](#), [Further Documentation](#)

perlform, [Formats](#)

perlfunc, [Formatted Output with printf](#), [The Naked Block Control Structure](#), [Mathematics](#), [System V IPC](#)

perlhist, [A Short History of Perl Development](#)

perlipc, [Getting Down and Dirty with fork](#), [System V IPC](#)

perllo, [Complex Data Structures](#)

perlobj, [Object-Oriented Programming](#)

perloutut, [Object-Oriented Programming](#)
perlop, [Operator Precedence and Associativity](#)
perlopentut, [More Ways to Open Filehandles](#)
perlpod, [Embedded Documentation](#)
perlpolicy, [Perl 5.10 and Beyond](#)
perlport, [The stat and lstat Functions](#)
perlre, [Choosing a Character Interpretation](#), [Regular Expressions](#)
perlref, [References](#)
perlrun, [Command-Line Options](#), [Reading from STDIN or Writing to STDOUT or STDERR](#)
perlsec, [Avoiding the Shell](#), [Security](#)
perlstyle, [What's Inside That Program?](#), [Choosing Good Variable Names](#)
perlsub, [Subroutine Signatures](#)
perlty, [Tied Variables](#)
perltoc, [Further Documentation](#)
perlunicode, [Choosing a Character Interpretation](#)
perluniprops, [Unicode Properties](#)
perlvar, [Choosing Good Variable Names](#)
permissions, [file and directory](#), [Modifying Permissions](#)
PFE (Programmer's File Editor), [How Do I Make a Perl Program?](#)
Pike, Rob, [UTF-8 and Friends](#)
piped open, [Processes as Filehandles](#)

plus (+) metacharacter, [Quantifiers](#), [Precedence](#)

.pm file extension, [Installing Modules](#), [Globbing](#), [Directory Handles](#)

pop() function, [The pop and push Operators](#)

POSIX module, [Avoiding the Shell](#), [Mathematics](#)

postderef feature, [Don't Rely on Experimental Features](#)

postderef_qq feature, [Don't Rely on Experimental Features](#)

pound sign (#), [What's Inside That Program?](#), [Adding Whitespace with /x](#)

pragmas, [Strings](#), [Perl's Built-in Warnings](#)

precedence

- in matching with regular expressions, [Precedence-And There's More](#)

- of operators, [Operator Precedence and Associativity-Operator Precedence and Associativity](#)

print() function

- debugging and, [Return Values](#)

- output with, [Output with print](#), [The Invocation Arguments](#)

- return value, [Return Values](#)

printf() function, [Formatted Output with printf-Arrays and printf](#),
[Formatting Data with sprintf](#), [Answers to Chapter 5 Exercises](#)

private variables in subroutines, [Private Variables in Subroutines](#), [Notes on Lexical \(my\) Variables](#), [Persistent](#), [Private Variables-Persistent](#), [Private Variables](#)

process management, [Process Management-Sending and Receiving Signals](#)

- about, [Process Management](#)

backquotes to capture output, [Using Backquotes to Capture Output-Using Backquotes in a List Context](#)

environment variables, [The Environment Variables-The Environment Variables](#)

exec() function, [The exec Function](#)

external processes, [External Processes with IPC::System::Simple](#)

low-level system calls, [Getting Down and Dirty with fork](#)

processes as filehandles, [Processes as Filehandles-Processes as Filehandles](#)

sending and receiving signals, [Sending and Receiving Signals-Sending and Receiving Signals](#)

system() function, [The system Function-Avoiding the Shell](#)

processing text with regular expressions

in-place editing, [Updating Many Files-Updating Many Files](#)

join() function, [The join Function](#)

m// in list context, [m// in List Context](#)

multiple-line text, [Matching Multiple-Line Text](#)

nongreedy quantifiers, [Nongreedy Quantifiers](#)

split operator, [The split Operator-The split Operator](#)

substitutions with s///, [Substitutions with s///-Metaquoting](#)

updating multiple files, [Updating Many Files-In-Place Editing from the Command Line](#)

word boundaries, [Fancier Word Boundaries](#)

programmer's text editors, [How Do I Make a Perl Program?](#), [Matches with m//](#)

prototypes, [Prototypes](#)

push() function, [The pop and push Operators](#)

Q

\Q escape, [Metaquoting](#)

quantifiers in regular expressions

about, [Quantifiers-Quantifiers](#)

greedy, [Quantifiers](#)

nongreedy, [Nongreedy Quantifiers](#)

order of precedence, [Precedence](#)

question mark (?) metacharacter, [Quantifiers](#), [Precedence](#)

quotation marks

in list quoting with qw(), [The qw Shortcut](#)

string literals, [Single-Quoted String Literals-Double-Quoted String Literals](#)

variable interpolation and, [Interpolation of Scalar Variables into Strings](#)

quotemeta() function, [Metaquoting](#)

qw()() function, [The qw Shortcut](#)

qx() function, [Using Backquotes to Capture Output](#)

R

`\R` (linebreak) shortcut, [Character Class Shortcuts](#)

`-r` file test, [File Test Operators](#)

`-R` file test, [File Test Operators](#)

`/r` modifier, [Nondestructive Substitutions](#)

radix of numbers, [Interpreting Nondecimal Numerals](#)

range operator (`..`), [List Literals](#)

`readdir()` function, [Directory Handles](#)

`readline()` function, [An Alternate Syntax for Globbing](#)

`readlink()` function, [Links and Files](#)

`redo()` function, [The redo Operator](#)

refaliasing feature, [Don't Rely on Experimental Features](#)

references

- about, [List Assignment, References](#)

- anonymous subroutines, [Anonymous Subroutines and Closures](#)

- back, [Grouping in Patterns-Grouping in Patterns](#)

- closures, [Anonymous Subroutines and Closures](#)

- complex data structures, [Complex Data Structures](#)

- object-oriented programming, [Object-Oriented Programming](#)

`Regexp::Debugger` module, [Quantifiers](#)

`regex_sets` feature, [Don't Rely on Experimental Features](#)

regular expressions, [Regular Expressions-Word Anchors](#)

- about, [Regular Expressions](#)

additional sources, [Regular Expressions](#)

alternation, [Alternation-Alternation](#)

anchors for, [Anchors-Word Anchors](#), [Precedence](#)

character classes, [Character Classes-Negating the Shortcuts](#)

grouping in patterns, [Grouping in Patterns-Grouping in Patterns](#)

matching with, [Matching with Regular Expressions-A Pattern Test Program](#)

pattern practice examples, [Practice Some Patterns-Practice Some Patterns](#)

processing text with, [Processing Text with Regular Expressions-In-Place Editing from the Command Line](#)

quantifiers in, [Quantifiers-Quantifiers](#), [Precedence](#)

sequences, [Sequences-Sequences](#), [Precedence](#)

Unicode properties, [Unicode Properties](#)

wildcards in, [The Wildcard](#)

relative back reference, [Grouping in Patterns](#)

relative path (file), [The Current Working Directory](#)

rename() function, [Renaming Files-Renaming Files](#)

repeat operators, [Quantifiers](#), [Precedence](#)

reporting bugs in Perl, [What If I Find a Bug in Perl?](#)

return values in subroutines

about, [Return Values-Return Values](#)

nonscalar, [Nonscalar Return Values](#)

return() function and, [The return Operator-Omitting the Ampersand](#)
return() function, [The return Operator-Omitting the Ampersand](#)
reverse() function
 about, [The reverse Operator](#)
 hash assignment and, [Hash Assignment](#)
 list context and, [Using List-Producing Expressions in Scalar Context](#),
 [Answers to Chapter 5 Exercises](#)
 sort subroutine and, [Advanced Sorting](#)
rindex() function, [Finding a Substring with index](#)
rm Unix command, [Removing Files](#), [The Environment Variables](#)
rmdir() function, [Making and Removing Directories](#)

S

-s file test, [File Test Operators](#)
-S file test, [File Test Operators](#)
%s format, [Formatted Output with printf](#)
/s modifier, [Matching Any Character with /s](#), [Substitution Modifiers](#)
\s (whitespace) shortcut, [Character Class Shortcuts](#)
s/// (substitution operator)
 about, [Substitutions with s///](#)
 binding operator, [The Binding Operator](#)
 case shifting, [Case Shifting-Case Shifting](#)
 different delimiters, [Different Delimiters](#)

global replacements with /g, [Global Replacements with /g](#)

metaquoting, [Metaquoting](#)

nondestructive substitutions, [Nondestructive Substitutions](#)

/r switch, [Using Simple Modules](#), [Renaming Files](#)

substitution modifiers, [Substitution Modifiers](#)

substitutions with, [Substitutions with s///-Metaquoting](#)

Salzenberg, Chip, [A Short History of Perl Development](#)

say feature, [Don't Rely on Experimental Features](#)

say() function, [Output with say](#)

scalar context

about, [Scalar and List Context](#)

forcing, [Forcing Scalar Context](#)

list-producing expressions in, [Using List-Producing Expressions in Scalar Context](#)

sort() function and, [Using List-Producing Expressions in Scalar Context](#)

<STDIN> operator in, [Input from Standard Input](#)

scalar data

about, [Scalar Data](#)

built-in warnings, [Perl's Built-in Warnings-Interpreting Nondecimal Numerals](#)

getting user input, [Getting User Input](#)

if control structure, [The if Control Structure-Boolean Values](#)

numbers, [Numbers-Numeric Operators](#)

output with print() function, [Output with print](#)

strings, [Strings-Automatic Conversion Between Numbers and Strings](#)

while control structure, [The while Control Structure](#)

scalar variables, [Scalar Variables-Compound Assignment Operators](#)

about, [Scalar Data](#), [Scalar Variables](#)

assigning list values to, [List Assignment-The splice Operator](#)

autodecrementing, [Autoincrement and Autodecrement](#)

autoincrementing, [Autoincrement and Autodecrement-The Value of Autoincrement](#)

Boolean values, [Boolean Values](#)

built-in, [Built-in Variables](#)

chomp() function, [The chomp Operator](#)

choosing good names, [Choosing Good Variable Names](#)

compound assignment operators, [Compound Assignment Operators](#)

defined() function, [The defined Function](#)

filehandles in, [Filehandles in a Scalar-Filehandles in a Scalar](#)

interpolating into strings, [Double-Quoted String Literals](#), [Interpolation of Scalar Variables into Strings](#)

scalar assignment, [Scalar Assignment](#)

sigil and, [Scalar Variables](#)

tied, [Tied Variables](#)

undef value, [The undef Value](#)

scalar() function, [Forcing Scalar Context](#)

Scalar::Util module, [Using Bitstrings](#)

SciTE editor, [How Do I Make a Perl Program?](#)

security considerations, [Security](#)

select() function, [Changing the Default Output Filehandle](#)

semicolon (;), [What's Inside That Program?](#), [In-Place Editing from the Command Line](#)

sentence boundary, [Fancier Word Boundaries](#)

sequence patterns, [Sequences-Sequences](#), [Precedence](#)

shebang (!) line, [What's Inside That Program?](#)

shell commands, [A Simple Program](#), [Nondecimal Integer Literals](#)

shift() function, [The shift and unshift Operators](#), [Empty Parameter Lists](#)

short-circuit logical operators, [Logical Operators](#)

%SIG hash, [Sending and Receiving Signals](#)

SIGBUS signal, [Sending and Receiving Signals](#)

SIGCONT signal, [Sending and Receiving Signals](#)

SIGHUP signal, [Sending and Receiving Signals](#)

sigil (\$), [Scalar Variables](#)

SIGILL signal, [Sending and Receiving Signals](#)

SIGINT signal, [Sending and Receiving Signals](#)

signals, sending and receiving, [Sending and Receiving Signals-Sending and Receiving Signals](#)

signatures feature, [Experimental Features](#), [Don't Rely on Experimental Features](#)

Signes, Ricardo, [Perl 5.10 and Beyond](#)

SIGSEGV signal, [Sending and Receiving Signals](#)

SIGZERO signal, [Sending and Receiving Signals](#)

single quote ('), [Single-Quoted String Literals](#)

single-quoted string literals, [Single-Quoted String Literals](#)

slices, [Slices-Key-Value Slices](#)

- about, [Slices-Slices](#)

- array, [Array Slice-Array Slice](#)

- hash, [Hash Slice-Hash Slice](#)

- key-value, [Key-Value Slices](#)

- list, [Slices-Slices](#)

sockets, TCP/IP, [Sockets](#)

soft links, [Links and Files-Links and Files](#)

sort subroutine

- advanced examples, [Advanced Sorting-Sorting by Multiple Keys](#)

- sorting hashes by multiple keys, [Sorting by Multiple Keys](#)

- sorting hashes by value, [Sorting a Hash by Value](#)

sort Unix command, [Output to Standard Output](#), [Filehandles](#)

sort() function, [The sort Operator](#), [Using List-Producing Expressions in Scalar Context](#)

Space property, [Unicode Properties](#)

splice() function, [The splice Operator](#)

split operator, [The split Operator-The split Operator](#)

sprintf() function, [Formatting Data with sprintf-Using sprintf with “Money Numbers”](#)

sqrt() function, [The Naked Block Control Structure](#)

square brackets, [Interpolation of Scalar Variables into Strings, Hash Element Interpolation, Negating the Shortcuts](#)

standard error stream, [Filehandles](#)

standard input stream, [Filehandles](#)

standard output stream, [Filehandles](#)

star (*) metacharacter, [Quantifiers, Precedence](#)

stat() function, [Testing Several Attributes of the Same File, The stat and lstat Functions-The stat and lstat Functions, Changing Timestamps](#)

state feature, [Perl 5.10 and Beyond, Don’t Rely on Experimental Features](#)

state() function, [Persistent, Private Variables-Persistent, Private Variables](#)

statement modifiers, [Statement Modifiers-Statement Modifiers](#)

:std pragma, [Reading from STDIN or Writing to STDOUT or STDERR](#)

STDERR filehandle

- about, [Filehandles](#)

- reopening, [Reopening a Standard Filehandle](#)

- Unicode considerations, [Reading from STDIN or Writing to STDOUT or STDERR](#)

<STDIN> (line-input operator)

getting user input, [Getting User Input](#)

in list context, [<STDIN> in List Context](#), [Input from Standard Input](#)

in scalar context, [Input from Standard Input](#)

STDIN filehandle

about, [Getting User Input](#), [Filehandles](#)

reopening, [Reopening a Standard Filehandle](#)

Unicode considerations, [Reading from STDIN or Writing to STDOUT or STDERR](#)

STDOUT filehandle

about, [Filehandles](#)

reopening, [Reopening a Standard Filehandle](#)

Unicode considerations, [Reading from STDIN or Writing to STDOUT or STDERR](#)

strict pragma, [The use strict Pragma](#)-[The use strict Pragma](#), [Answers to Chapter 6 Exercises](#)

string literals

about, [Single-Quoted String Literals](#)

double-quoted, [Double-Quoted String Literals](#), [Sequences](#)

single-quoted, [Single-Quoted String Literals](#)

string operators, [String Operators](#), [Compound Assignment Operators](#)

string repetition operator, [String Operators](#)

strings

about, [Single-Quoted String Literals](#)

bitstrings, [Using Bitstrings-Using Bitstrings](#)

comparison operators, [Comparison Operators](#)

converting to numbers, [Automatic Conversion Between Numbers and Strings](#)

creating characters by code point, [Creating Characters by Code Point](#)

empty, [Strings, Interpolation of Scalar Variables into Strings](#)

finding substrings with index() function, [Finding a Substring with index-Finding a Substring with index](#)

formatting data with sprintf() function, [Formatting Data with sprintf-Using sprintf with “Money Numbers”](#)

hash keys as, [What Is a Hash?](#)

interpolating arrays into, [Interpolating Arrays into Strings, Output to Standard Output](#)

interpolating hash elements into, [Hash Element Interpolation](#)

joining, [The join Function](#)

manipulating substrings with substr() function, [Manipulating a Substring with substr-Manipulating a Substring with substr](#)

match variables and, [The Match Variables-The Automatic Match Variables](#)

qw() function and, [The qw Shortcut](#)

splitting, [The split Operator-The split Operator](#)

variable interpolation into, [Double-Quoted String Literals, Interpolation of Scalar Variables into Strings](#)

Sublime Text editor, [How Do I Make a Perl Program?](#)

subroutine signatures, [Subroutine Signatures-Prototypes](#)

subroutines

about, [Subroutines](#)

ampersands and, [Subroutines, Omitting the Ampersand-Omitting the Ampersand](#)

anonymous, [Anonymous Subroutines and Closures](#)

arguments in, [Arguments-Arguments](#)

defining, [Defining a Subroutine](#)

invoking, [Invoking a Subroutine](#)

lexical variables, [Persistent, Private Variables-Persistent, Private Variables](#)

lexical variables in, [Notes on Lexical \(my\) Variables](#)

private variables in, [Private Variables in Subroutines](#)

prototypes and, [Prototypes](#)

return values, [Return Values-Return Values, Nonscalar Return Values](#)

return() function and, [The return Operator-Omitting the Ampersand](#)

Unicode support, [Fancier Characters](#)

use strict pragma, [The use strict Pragma-The use strict Pragma](#)

variable-length parameter lists, [Variable-Length Parameter Lists-Empty Parameter Lists](#)

substr() function, [Manipulating a Substring with substr-Manipulating a Substring with substr](#)

substrings

finding with index() function, [Finding a Substring with index-Finding a Substring with index](#)

manipulating with substr() function, [Manipulating a Substring with substr-Manipulating a Substring with substr](#)

switch feature, [Don't Rely on Experimental Features](#)

symbolic links, [Links and Files-Links and Files](#)

symlink() function, [Links and Files](#)

System V IPC (interprocess communication), [System V IPC](#)

system() function, [The system Function-Avoiding the Shell](#)

T

-t file test, [File Test Operators](#)

-T file test, [File Test Operators](#)

taint checking, [Security](#)

tar Unix command, [Avoiding the Shell](#)

TCP/IP sockets, [Sockets](#)

text editors, [How Do I Make a Perl Program?](#), [Matches with m//](#)

Text::CSV_XS module, [The split Operator](#)

TextMate editor, [How Do I Make a Perl Program?](#)

Thompson, Ken, [UTF-8 and Friends](#)

tied variables, [Tied Variables](#)

time and date modules, [Dates and Times](#)

Time::Moment module, [Dates and Times](#)

timestamps, file, [Changing Timestamps](#)

try-catch feature, [Don't Rely on Experimental Features](#)

Try::Tiny module, [More Advanced Error Handling](#)

U

\U escape, [Case Shifting](#)

\u escape, [Case Shifting](#)

-u file test, [File Test Operators](#)

uc() function, [Case Shifting](#)

ucfirst() function, [Case Shifting](#)

UCS (Universal Character Set), [Unicode](#)

UltraEdit editor, [How Do I Make a Perl Program?](#)

undef value

- about, [The undef Value](#)

- array elements, [Accessing Elements of an Array](#)

- end-of-file and, [Bad Filehandles](#)

- remedy for, [Answers to Chapter 4 Exercises](#)

underscore (`_`), [Integer Literals](#), [Choosing Good Variable Names](#), [The use strict Pragma](#)

Unicode

- about, [Unicode](#)

- case-folding bug, [Choosing a Character Interpretation](#)

- creating characters by code point, [Creating Characters by Code Point](#)

fancy characters, [Fancy Characters-Fancier Characters](#)

Perl support, [Strings, Dealing with Unicode in Perl-Dealing with Databases](#)

regular expressions and, [Unicode Properties](#)

setting up usage, [Getting Everyone to Agree](#)

using in source code, [Using Unicode in Your Source](#)

UTF-8 encoding, [Strings, UTF-8 and Friends, Using Unicode in Your Source](#)

Unicode Consortium, [Unicode Properties](#)

Unicode::Casing module, [Case Shifting](#)

Unicode::Normalize module, [Fancier Characters](#)

unicode_eval feature, [Don't Rely on Experimental Features](#)

unicode_strings feature, [Don't Rely on Experimental Features](#)

unicore directory, [Unicode](#)

Universal Character Set (UCS), [Unicode](#)

unless control structure, [The unless Control Structure-The else Clause with unless](#)

unlink() function, [Removing Files-Removing Files, Making and Removing Directories](#)

unshift() function, [The shift and unshift Operators](#)

until control structure, [The until Control Structure, The last Operator](#)

unwinding hashes, [The Hash as a Whole](#)

updating multiple files, [Updating Many Files-Updating Many Files](#)

use() function

diagnostics pragma, [Perl's Built-in Warnings](#)

strict pragma, [The use strict Pragma-The use strict Pragma](#), [Answers to Chapter 6 Exercises](#)

warnings pragma, [Bad Filehandles](#), [Using eval](#)

user input, getting, [Getting User Input](#)

UTF-16 encoding, [Opening a Filehandle](#), [UTF-8 and Friends](#)

UTF-8 encoding, [Strings](#), [Opening a Filehandle](#), [UTF-8 and Friends](#), [Using Unicode in Your Source](#)

utf8 pragma, [Strings](#), [Scalar Variables](#), [Using Unicode in Your Source](#)

utime() function, [Changing Timestamps](#)

V

values() function, [The keys and values Functions](#)

variable interpolation, [Double-Quoted String Literals](#), [Interpolation of Scalar Variables into Strings](#), [Practice Some Patterns](#)

vec operator, [Bits and Pieces](#)

VERBOSE environment variable, [The defined-or Operator](#)

vertical bar (|) of alternation, [Alternation-Alternation](#), [Precedence](#)

vi editor, [How Do I Make a Perl Program?](#)

Vincent, Jesse, [Perl 5.10 and Beyond](#)

vlb feature, [Don't Rely on Experimental Features](#)

W

\w (word) shortcut, [Character Class Shortcuts](#)

-w file test, [File Test Operators](#)

-W file test, [File Test Operators](#)

waitpid() function, [Getting Down and Dirty with fork](#)

Wall, Larry, [What Does “Perl” Stand For?, A Short History of Perl Development](#)

wantarray() function, [Nonscalar Return Values](#)

warn() function, [Warning Messages with warn](#)

warnings

- bad filehandles, [Bad Filehandles](#)

- built-in, [Perl’s Built-in Warnings-Interpreting Nondecimal Numerals](#)

- experimental, [Turning Off Experimental Warnings](#)

- print() function, [Bad Filehandles](#)

- warn() function and, [Warning Messages with warn](#)

warnings pragma, [Bad Filehandles](#), [Using eval](#)

while control structure

- about, [The while Control Structure](#)

- each() function and, [The each Function-The each Function](#)

- infinite loops, [The for Control Structure](#)

- lexical variables in, [Notes on Lexical \(my\) Variables](#)

- loop controls, [The last Operator](#)

- pattern matching and, [The Persistence of Captures](#)

until control structure and, [The until Control Structure](#)

whitespace

/x modifier and, [Adding Whitespace with /x](#)

character class shortcuts and, [Character Class Shortcuts](#)

character classes and, [Whitespace in character classes](#)

collapsing, [Global Replacements with /g](#)

qw() function and, [The qw Shortcut](#)

splitting on, [The split Operator](#)

who Unix command, [Using Backquotes in a List Context](#)

wildcards in regular expressions, [The Wildcard](#)

Win32::Process module, [Getting Down and Dirty with fork](#)

word anchors, [Word Anchors](#), [Fancier Word Boundaries](#)

word operators, [Control Structures Using Partial-Evaluation Operators](#)

word processors, [How Do I Make a Perl Program?](#)

working directory, [The Current Working Directory-The Current Working Directory](#)

WWW::Mechanize module, [Sockets](#)

X

-x file test, [File Test Operators](#)

-X file test, [File Test Operators](#)

%x format, [Formatted Output with printf](#)

/x modifier, [Adding Whitespace with /x](#), [Substitution Modifiers](#)

xor operator, [Control Structures Using Partial-Evaluation Operators](#)

/xx modifier, [Whitespace in character classes](#)

Y

yada yada operator (...), [The foreach Control Structure](#)

Z

\z anchor, [Anchors](#)

\Z anchor, [Anchors](#)

-z file test, [File Test Operators](#)

zero, indexing elements of lists/arrays, [Lists and Arrays](#)

zero-width assertions, [Anchors](#)

1. Preface

- a. Typographical Conventions
- b. Code Examples
- c. O'Reilly Online Learning
- d. How to Contact Us
- e. History of This Book
- f. Changes from the Previous Edition
- g. Acknowledgments
 - i. From Randal
 - ii. From brian
 - iii. From Tom
 - iv. From All of Us

2. 1. Introduction

- a. Questions and Answers
 - i. Is This the Right Book for You?
 - ii. What About the Exercises and Their Answers?
 - iii. What If I'm a Perl Course Instructor?
- b. What Does "Perl" Stand For?
 - i. Why Did Larry Create Perl?
 - ii. Why Didn't Larry Just Use Some Other Language?
 - iii. Is Perl Easy or Hard?

- iv. How Did Perl Get to Be So Popular?
 - v. What's Happening with Perl Now?
 - vi. What's Perl Really Good For?
 - vii. What Is Perl Not Good For?
- c. How Can I Get Perl?
 - i. What Is CPAN?
 - ii. Is There Any Kind of Support?
 - iii. What If I Find a Bug in Perl?
- d. How Do I Make a Perl Program?
 - i. A Simple Program
 - ii. What's Inside That Program?
 - iii. How Do I Compile My Perl Program?
- e. A Whirlwind Tour of Perl
- f. Exercises

3. 2. Scalar Data

- a. Numbers
 - i. All Numbers Have the Same Format Internally
 - ii. Integer Literals
 - iii. Nondecimal Integer Literals
 - iv. Floating-Point Literals
 - v. Numeric Operators
- b. Strings

- i. Single-Quoted String Literals
 - ii. Double-Quoted String Literals
 - iii. String Operators
 - iv. Automatic Conversion Between Numbers and Strings
- c. Perl's Built-in Warnings
 - i. Interpreting Nondecimal Numerals
- d. Scalar Variables
 - i. Choosing Good Variable Names
 - ii. Scalar Assignment
 - iii. Compound Assignment Operators
- e. Output with print
 - i. Interpolation of Scalar Variables into Strings
 - ii. Creating Characters by Code Point
 - iii. Operator Precedence and Associativity
 - iv. Comparison Operators
- f. The if Control Structure
 - i. Boolean Values
- g. Getting User Input
- h. The chomp Operator
 - i. The while Control Structure
- j. The undef Value

- k. The defined Function

- l. Exercises

4. 3. Lists and Arrays

- a. Accessing Elements of an Array

- b. Special Array Indices

- c. List Literals

- i. The qw Shortcut

- d. List Assignment

- i. The pop and push Operators

- ii. The shift and unshift Operators

- iii. The splice Operator

- e. Interpolating Arrays into Strings

- f. The foreach Control Structure

- i. Perl's Favorite Default: \$_

- ii. The reverse Operator

- iii. The sort Operator

- iv. The each Operator

- g. Scalar and List Context

- i. Using List-Producing Expressions in Scalar Context

- ii. Using Scalar-Producing Expressions in List Context

- iii. Forcing Scalar Context

- h. <STDIN> in List Context

- i. Exercises

5. 4. Subroutines

- a. Defining a Subroutine

- b. Invoking a Subroutine

- c. Return Values

- d. Arguments

- e. Private Variables in Subroutines

- f. Variable-Length Parameter Lists

- i. A Better &max Routine

- ii. Empty Parameter Lists

- g. Notes on Lexical (my) Variables

- h. The use strict Pragma

- i. The return Operator

- i. Omitting the Ampersand

- j. Nonscalar Return Values

- k. Persistent, Private Variables

- l. Subroutine Signatures

- i. Prototypes

- m. Exercises

6. 5. Input and Output

- a. Input from Standard Input

- b. Input from the Diamond Operator
 - i. The Double Diamond
- c. The Invocation Arguments
- d. Output to Standard Output
- e. Formatted Output with printf
 - i. Arrays and printf
- f. Filehandles
- g. Opening a Filehandle
 - i. Binmoding Filehandles
 - ii. Bad Filehandles
 - iii. Closing a Filehandle
- h. Fatal Errors with die
 - i. Warning Messages with warn
 - ii. Automatically die-ing
- i. Using Filehandles
 - i. Changing the Default Output Filehandle
- j. Reopening a Standard Filehandle
- k. Output with say
- l. Filehandles in a Scalar
- m. Exercises

7. 6. Hashes

- a. What Is a Hash?

- i. Why Use a Hash?
 - b. Hash Element Access
 - i. The Hash as a Whole
 - ii. Hash Assignment
 - iii. The Big Arrow
 - c. Hash Functions
 - i. The keys and values Functions
 - ii. The each Function
 - d. Typical Use of a Hash
 - i. The exists Function
 - ii. The delete Function
 - iii. Hash Element Interpolation
 - e. The %ENV Hash
 - f. Exercises
- 8. 7. Regular Expressions
 - a. Sequences
 - b. Practice Some Patterns
 - c. The Wildcard
 - d. Quantifiers
 - e. Grouping in Patterns
 - f. Alternation
 - g. Character Classes

- i. Character Class Shortcuts
 - ii. Negating the Shortcuts
 - h. Unicode Properties
 - i. Anchors
 - i. Word Anchors
 - j. Exercises
- 9. 8. Matching with Regular Expressions
 - a. Matches with m//
 - b. Match Modifiers
 - i. Case-Insensitive Matching with /i
 - ii. Matching Any Character with /s
 - iii. Adding Whitespace with /x
 - iv. Combining Option Modifiers
 - v. Choosing a Character Interpretation
 - vi. Beginning- and End-of-Line Anchors
 - vii. Other Options
 - c. The Binding Operator =~
 - d. The Match Variables
 - i. The Persistence of Captures
 - ii. Captures in Alternations
 - iii. Noncapturing Parentheses
 - iv. Named Captures

- v. The Automatic Match Variables

- e. Precedence

- i. Examples of Precedence

- ii. And There's More

- f. A Pattern Test Program

- g. Exercises

10. 9. Processing Text with Regular Expressions

- a. Substitutions with `s///`

- i. Global Replacements with `/g`

- ii. Different Delimiters

- iii. Substitution Modifiers

- iv. The Binding Operator

- v. Nondestructive Substitutions

- vi. Case Shifting

- vii. Metaquoting

- b. The `split` Operator

- c. The `join` Function

- d. `m//` in List Context

- e. More Powerful Regular Expressions

- i. Nongreedy Quantifiers

- ii. Fancier Word Boundaries

- iii. Matching Multiple-Line Text

iv. Updating Many Files

v. In-Place Editing from the Command Line

f. Exercises

11. 10. More Control Structures

a. The unless Control Structure

i. The else Clause with unless

b. The until Control Structure

c. Statement Modifiers

d. The Naked Block Control Structure

e. The elsif Clause

f. Autoincrement and Autodecrement

i. The Value of Autoincrement

g. The for Control Structure

i. The Secret Connection Between foreach and for

h. Loop Controls

i. The last Operator

ii. The next Operator

iii. The redo Operator

iv. Labeled Blocks

i. The Conditional Operator

j. Logical Operators

i. The Value of a Short-Circuit Operator

- ii. The defined-or Operator
- iii. Control Structures Using Partial-Evaluation Operators

- k. Exercises

12. 11. Perl Modules

- a. Finding Modules
- b. Installing Modules
 - i. Using Your Own Directories
- c. Using Simple Modules
 - i. The File::Basename Module
 - ii. Using Only Some Functions from a Module
 - iii. The File::Spec Module
 - iv. Path::Class
 - v. Databases and DBI
 - vi. Dates and Times
- d. Exercises

13. 12. File Tests

- a. File Test Operators
 - i. Testing Several Attributes of the Same File
 - ii. Stacked File Test Operators
- b. The stat and lstat Functions
- c. The localtime Function

- d. Bitwise Operators
 - i. Using Bitstrings
- e. Exercises

14. 13. Directory Operations

- a. The Current Working Directory
- b. Changing the Directory
- c. Globbing
- d. An Alternate Syntax for Globbing
- e. Directory Handles
- f. Manipulating Files and Directories
- g. Removing Files
- h. Renaming Files
- i. Links and Files
- j. Making and Removing Directories
- k. Modifying Permissions
 - l. Changing Ownership
- m. Changing Timestamps
- n. Exercises

15. 14. Strings and Sorting

- a. Finding a Substring with index
- b. Manipulating a Substring with substr
- c. Formatting Data with sprintf

- i. Using sprintf with “Money Numbers”
- d. Advanced Sorting
 - i. Sorting a Hash by Value
 - ii. Sorting by Multiple Keys
- e. Exercises

16. 15. Process Management

- a. The system Function
 - i. Avoiding the Shell
- b. The Environment Variables
- c. The exec Function
- d. Using Backquotes to Capture Output
 - i. Using Backquotes in a List Context
- e. External Processes with IPC::System::Simple
- f. Processes as Filehandles
- g. Getting Down and Dirty with fork
- h. Sending and Receiving Signals
- i. Exercises

17. 16. Some Advanced Perl Techniques

- a. Slices
 - i. Array Slice
 - ii. Hash Slice
 - iii. Key-Value Slices

- b. Trapping Errors
 - i. Using eval
 - ii. More Advanced Error Handling
- c. Picking Items from a List with grep
- d. Transforming Items from a List with map
- e. Fancier List Utilities
- f. Exercises

18. A. Exercise Answers

- a. Answers to Chapter 1 Exercises
- b. Answers to Chapter 2 Exercises
- c. Answers to Chapter 3 Exercises
- d. Answers to Chapter 4 Exercises
- e. Answers to Chapter 5 Exercises
- f. Answers to Chapter 6 Exercises
- g. Answers to Chapter 7 Exercises
- h. Answers to Chapter 8 Exercises
- i. Answers to Chapter 9 Exercises
- j. Answers to Chapter 10 Exercises
- k. Answers to Chapter 11 Exercises
- l. Answers to Chapter 12 Exercises
- m. Answers to Chapter 13 Exercises
- n. Answers to Chapter 14 Exercises

- o. Answers to Chapter 15 Exercises
- p. Answers to Chapter 16 Exercises

19. B. Beyond the Llama

- a. Further Documentation
- b. Regular Expressions
- c. Packages
- d. Extending Perl's Functionality
 - i. Writing Your Own Modules
- e. Databases
- f. Mathematics
- g. Lists and Arrays
- h. Bits and Pieces
- i. Formats
- j. Networking and IPC
 - i. System V IPC
 - ii. Sockets
- k. Security
- l. Debugging
- m. Command-Line Options
- n. Built-in Variables
- o. References
 - i. Complex Data Structures

- ii. Object-Oriented Programming
 - iii. Anonymous Subroutines and Closures
- p. Tied Variables
- q. Operator Overloading
- r. Using Other Languages Inside Perl
- s. Embedding
- t. Converting find Command Lines to Perl
- u. Command-Line Options in Your Programs
- v. Embedded Documentation
- w. More Ways to Open Filehandles
- x. Graphical User Interfaces (GUIs)
- y. And More...

20. C. A Unicode Primer

- a. Unicode
- b. UTF-8 and Friends
- c. Getting Everyone to Agree
- d. Fancy Characters
 - i. Using Unicode in Your Source
 - ii. Fancier Characters
- e. Dealing with Unicode in Perl
 - i. Fancier Characters by Name
 - ii. Reading from STDIN or Writing to STDOUT or STDERR

- iii. Reading from and Writing to Files
- iv. Dealing with Command-Line Arguments
- v. Dealing with Databases

- f. Further Reading

21. D. Experimental Features

- a. A Short History of Perl Development
 - i. Perl 5.10 and Beyond
- b. Installing a Recent Perl
- c. Experimental Features
 - i. Turning Off Experimental Warnings
 - ii. Enable or Disable Features Lexically
 - iii. Don't Rely on Experimental Features

22. Index